Managing Information for Effective Product Innovation: A Contingency Approach

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Studying for a Ph.D. is a process similar to the development of a new product. It begins with the application of an interesting idea or the need to bridge the gap of unsatisfied demand (i.e., theoretical gap). It ends with a new product that contributes to the pool of human knowledge and, meanwhile, provides great rewards when the Ph.D. dream comes true. The process involves challenge, hard-work, learning, and fun. It is an effort of information processing/assimilation and knowledge creation/accumulation. More important, it is a lonely process that needs the hand-grasp and the word of cheer -- therefore, I owe many people a lot.

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Finally, thanks to myself. Ting-Jui, well done!

Declaration

1. This work is composed by me.
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ABSTRACT

Is it beneficial for firms to tailor their new product development (NPD) strategies to accommodate different project situations/conditions? This thesis examines the applicability of contingency theory to product innovation management. Based on an extensive literature review, information processing and knowledge accumulation are interpreted as the cognitive core of NPD, which further forms the basis of this study. The concept of "fit" provides a necessary focus for statistical analyses, where information processing and organisational learning models are presented to compare the use of these models and their associated NPD contingent situations/conditions.

The development of the research instrument was guided by previous literature and its validity and reliability tested in a pilot study. A project-level study involving 112 NPD cases from 53 Taiwanese firms, selected via a representative sampling design, was undertaken. Research data were acquired via a semi-structural questionnaire and through in-depth interviews with managers. Both qualitative and quantitative techniques were applied, to examine the nature of the research domain, and to retain the ability to generalize research findings to the sampling frame.

This study provides better insight into the dynamics of product innovation. Multivariate techniques were successfully used to develop a typology for differentiating NPD projects. For consideration of internal contingent factors, NPD projects were classified into Easy-to-Produce Radicals, Hard-to-Produce Radicals, Untried Incrementals, and Tried and Tested Incrementals. For consideration of external contingent factors, three NPD market conditions were identified, i.e., Turbulent Market, Declining Market, and Stable Market. The findings suggest that internal contingent factors strongly affect the pattern of project-level information processing, knowledge accumulation, and NPD structural design, while external contingent factors have a limited effect upon NPD.

This study contributes to NPD management theory in three key areas: (1) The hidden structure of NPD contingencies is uncovered in a systematic way. This provides a basis for future studies, in which these contingent factors can be controlled and the effect on other NPD activities can be observed more closely. (2) By combining qualitative and quantitative techniques in a single research design, both the structure and the process of product innovation are observed. This allowed the researcher to present a more detailed anatomy of NPD information processing. (3) Previous academic work into NPD contingency management was mainly based on hypothesized contingency variables, such as radical/incremental innovations or routine/nonroutine tasks; these classifications are too broad and fail to reveal the true nature of NPD. The current study differentiates NPD projects based on situations/conditions empirically identified from fieldwork; this further extends the frontier of conventional NPD contingency studies.

Chapter One

Introduction

1

Products fail from a lack of planning;

planning fails from a lack of information.

(Wheelwright and Sasser, Jr., 1989: 113)

1 Introduction

§1.1 Emphasis on New Product Development

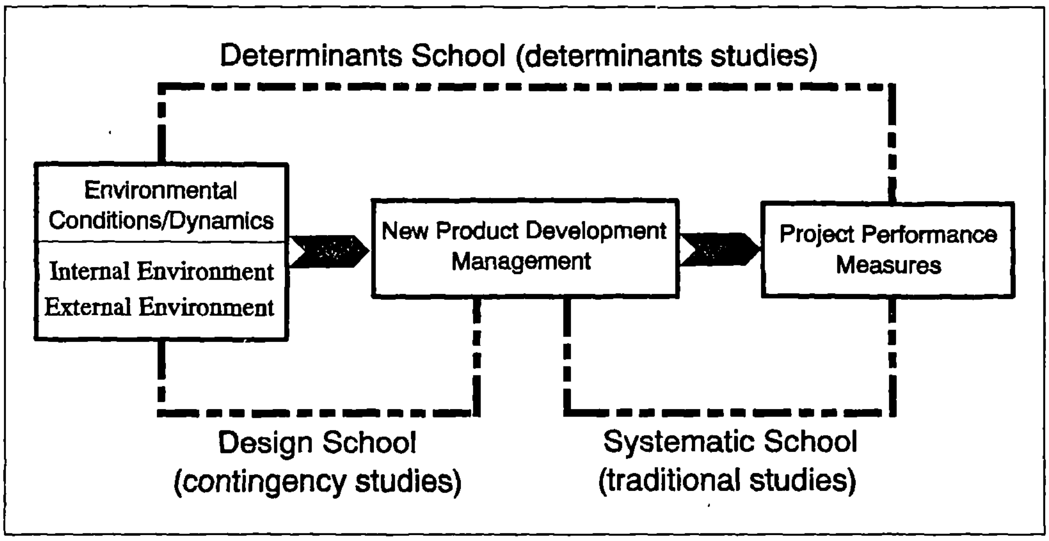
New Product Development (NPD) is one of the key activities in today's corporation management. In a 1984 survey, Myers (1986: 317) reported that the chief marketing officers from 125 American firms rated new product introduction the second most important source of pressure in their managerial life. Many studies also pointed out that the launch of new products in effect determines the financial performance of modern companies. The average impact of new products upon company sales and profits was about 25% to 30% (Cooper, 1984; Fraker, 1984; Particelli and Killips, 1986; Takeuchi and Nonaka, 1986), while in some high-tech industries such figures can be as high as 90% (Bonnet, 1986). As a result, in the last few decades a great amount of academic research has sought to identify factors influencing NPD performance. For example, from 1986 to early 1995, according to the ABI/INFORM database, there were 14,411 journal articles written in English looking into the management of new product development. In 1994 there were more than 300 books in print for English readers that were relevant to product innovation.

While these academic efforts have shed light on our understanding of product innovation management, industrial practices still encountered enormous difficulty in developing successful new products. For example, Mansfield and Wagner (1975) reported a 73% failure rate for new industrial products and an 84% failure rate for consumer products. In 1982 the well-established Booz, Allen, and Hamilton report concluded that 75 out of 100 new product projects eventually failed after commercialisation. In 1985, Fortune estimated an 80% failure rate of new product launch in the US market. More recently, Calantone et al. (1995: 218) reported a striking truth - that only 7.7% of firms rated themselves as proficient in original product innovation. For two decades there was in effect little improvement in practical NPD management -- regardless of the great academic input into this arena. Does this suggest that previous NPD academic researches had no effect upon real-world practices?

§1.2 Why Do New Products Succeed or Fail?

Scholars have provided a variety of reasons to explain new product success and failure. These studies might be categorised into three broad streams or schools of thought: (a) the Determinants School, (b) the Systematic School, and (c) the Design School (see Figure 1.1). The Determinants School of thought assumed a "black box" style innovation process; the main concern in NPD strategic formulation is the selection of a "suitable" project for the organisation, rather than the NPD management itself. On the other hand, the Systematic School studies stressed the importance of a systematic NPD implementation. They argued that if, and only if, the whole process of NPD is well managed in a specific way, can a positive commercialisation result from the project. While the Determinants School of thought focused only on the investigation of the non-managerial issues and the Systematic School of thought stressed only internal project implementation, the Design School studies combined the two, generating an integrated view of NPD reality. With insight drawn from contingency theory of organisational studies, this stream of thought regarded the NPD process as an open system that is contingent upon its external and internal environment. NPD management should be tailored for, and

Figure 1.1 The Main Approaches in Product Innovation Studies



adapted to, the corresponding project situations/conditions, thereby assuring a desirable project outcome.

The most commonly cited cause for new product failure by the Determinants School studies was the faulty selection of a project that does not fit the firm (e.g., Cooper, 1978, 1992). Many scholars therefore suggested that *prior hoc* factors based on the initial project situations/ conditions may predict final project outcomes (e.g., Baker et al., 1986; Calantone et al., 1993; Cooper, 1978, 1981, 1992; Cooper and Kleinschmidt, 1987abc, 1990, 1993; Cooper et al., 1994; de Brentani and Cooper, 1992; Maidique and Zirger, 1984; Parry and Song, 1994). Quantitative forecast models were developed in an attempt to provide means for screening out the "bad" project ideas before conducting NPD. To do this, firms have to acquire sufficient information to understand their external environment, the nature of NPD projects, as well as their own strengths and weaknesses. The general rules for successful product innovation are to avoid high-risk radical projects, focus on attractive market segments, design a superior product that meets customer needs, and invest in familiar technologies.

While the model developers claimed the high validity of the above NPD screening models (e.g., Cooper, 1992), industrial experience reflects inadequate use of these models (e.g., Mahajan and Wind, 1992). The major criticisms lie in the inability of these models to reflect the internal and external dynamics of the NPD process and that screening criteria used in the models favour high familiarity projects. In practice, it has been shown that radical new products, and diversification of product lines, that is more risky and less familiar projects, are the major sources of corporate growth (Ansoff, 1957; Johnson and Jones, 1957; Foster, 1986). As such, risk-averse project selection models, while facilitating the task of project selection, may not be entirely appropriate for aiding evaluation and guiding execution of all types of new product project. The Systematic School scholars further suggested that the reason for new product failure was more due to the faulty approach of management, rather than the selection of NPD projects.

These Systematic School scholars believe that certain managerial rules are compulsory for successful product innovation. The main analytical perspectives of these researches consider: (1) the market and operating environment of the firm, (2) the actions or attributes of the firm as a whole, (3) the group of people within a firm involved in development work, and (4) particular individuals who are or ought to be involved (Johne and Snelson, 1988: 114). Some scholars treated NPD as part of the conventional general management that cannot be separated from overall corporate managerial operations. They argued that NPD, like other functional activities, requires an integrated system which links corporate strategic planning with operational level tactics (e.g., Johne and Snelson, 1988, Dwyer, 1990; Grady and Fincham, 1990). Such integration includes the commitment of vision, mission, and strategy at top management level (e.g., Mansfield, 1981; Quinn, 1985; Shrivastava and Souder, 1987; Peters, 1990), as well as the consideration of shared values (e.g., van de Ven, 1986; Ansoff, 1987; Peters, 1991), management style (e.g., Rochford, 1991; Johne, 1992), and structural arrangement (e.g., Jermakowicz, 1978; Kumpe and Bolwijn, Grady and Fincham, 1990; 1994) for the company as a whole.

More importantly, most scholars from this school of thought stressed the impact of good communication (or information management) upon successful NPD implementation. For example, T.J. Allen and his colleagues at MIT conducted a series of important researches into scientific communication patterns and concluded that the higher the intensity of communication within the research organisation, the better the performance of the research activities (Allen, 1966abc; Allen and Cohen, 1969; Allen and Fustfeld, 1975; Allen et al., 1980; Katz and Allen, 1982; Nochur and Allen, 1992). Scholars also pointed out that not only communications within R&D, but also inter-discipline coupling, decide new product success (e.g., Johnson and Jones, 1956; Olin, 1973; Phelps, 1977; Moenaert and Souder, 1990; Pinto and Pinto, 1990). Organisational redesign was therefore stressed so as to facilitate the dialogue between different functional departments (e.g., Shanklin and Ryans, 1984; Burt and Soukup, 1985; Bonnet, 1986; Souder, 1987, 1988; Gupta and Wilemon, 1988, 1990; Thurmond and Kunak, 1988; van Dierdonck, 1990; Good, 1991).

The Design School scholars suggested a somewhat evolutionary view of NPD management. They argued that new product performance is in effect determined by the process of adaptation of managerial strategy during product innovation, rather than the selection of a favourable project or attention to any compulsory rule for effective NPD management. They asserted that managerial efforts should be tailored specifically to a particular task so as to reflect the particular requirements embedded in the task and its incumbent environment (e.g., Holland et al., 1976; Jermakowicz, 1978; Tushman, 1979; Johne, 1984; Allen, 1986; Shrivastava and Souder, 1987; Thurmond and Kunak, 1988; Brown and Karagozoglu, 1989; Fleischer and Liker, 1992; Shenhar, 1993; Keller, 1994; Atuahene-Gima, 1995). The winners are those who can quickly adopt the right NPD strategy for a particular project at the right time. This is done through the intelligent use of NPD management techniques as well as a thorough understanding of the internal and external nature of the project itself.

§1.3 The Consensus in Previous Research Findings: Information Management as a Key to Effective Product Innovation

Despite the differences in the way scholars perceived the nature of NPD management, a common theme can, however, be found throughout previous research investigations, that is, the importance of information. For the Determinants School scholars, information is highly critical because it provides the basic understanding of internal and external project situations/conditions. For the Systematic School, information/communication is in effect the focus of NPD implementation. For the Design School, information processing is not only the main concern when executing product innovation, but also the means by which new product players sense the internal and external NPD environment.

Scholars therefore asserted that information processing and knowledge accumulation, in essence, comprise the basic nature of innovation management (e.g., Allen, 1966b, 1970, Allen and Cohen, 1969; Rothwell et al., 1974; Cooper, 1979; Epton, 1981; Maidique and Zirger, 1984; Baker et al., 1986; Cooper et al., 1994). Other scholars in addition suggested mechanisms for fostering information transmission within and between functional departments (e.g., Hall and Ritchie, 1975; Pruthi and Nagpaul, 1978; Bonnet, 1986; Souder, 1987; Griffin and Hauser, 1992; Moenaert et al., 1994). Furthermore, observations based on successful Japanese experiences stressed the role of information in new product development (e.g., Golberg et al., 1981; Aoki, 1986, 1988, 1990; Nonaka, 1990, 1991; Kodama, 1992; McKee, 1992). A redundant mode of information sharing that has been highlighted, with particular emphasis given to the facilitation of organisational learning which is critical for successful product innovation.

§1.4 Key Limitations in Previous Research

Thus each school of thought has its own view on how product innovation should be managed. However, as new product failure rates in western industries remain high, one may query if these previous efforts have had a significant influence on managerial practices. New product managers may have learnt to be more effective, but the severity and intensity of competition have made it even more difficult to succeed consistently. The poor implementation of NPD may be due to a lack of proper translation of theoretical findings into real-world applications. It is also possible that such a situation is due to the unwillingness of industrial practitioners to use these theories because they do not reflect the reality of product innovation. Indeed, as researchers also tend to concentrate on their particular research interests, there are great differences in terms of their basic research assumptions and research approaches. Such variety, on the one hand, extends the scope of innovation management theory. On the other hand, it creates confusion in understanding of the applicability of innovation management theory to real life practices.

A Lack of Model Integrity

One of the major limitations in previous research is the lack of model integrity. An integrated model refers to the capability of the model to represent the multi-facets of a social event, based on the key perspective of such an event. Many previous studies into NPD management have concentrated only on single managerial activities, such as project screening (e.g., Cooper and Kleinschmidt, 1987abc; Cooper, 1992), laboratory management (e.g., Allen, 1970; Hauptman, 1986), organisational structure design (e.g,. Jermakowicz, 1978; Larson and Gobeli, 1988; Gray et al., 1990), or the management of organisational climate (e.g., Souder, 1987, 1988; Moenaert et al., 1994). However, product innovation is a complicated social event, which involves not only technology management, project screening, and process development, but also organisational re-engineering, strategic planning, marketing implementation, and many more activities. The focus on only one or two subjects in what is a wide-ranging activity cannot fully explain the essence of product innovation.

To draw a more integrated view of NPD management, one must identify the underlying nature of product innovation. As mentioned earlier in this chapter, information processing and knowledge accumulation in effect play a very important part in NPD activities. A focus on information management during product innovation may produce the necessary integrity of model development.

A Static View of NPD Reality

Product innovation is a continuous process rather than a series of isolated activities. The tasks involved in the whole process are in effect inseparable; the new product outcome is the result of a combined effect of all NPD efforts, and the quality of each task may influence the implementation of consequent ones. Furthermore, the timing, order, and emphasis of implementation of any single task may also be a significant cause of new product success or failure. However, previous researchers tend to restrict their investigation of NPD to a narrow/static slice of the whole process. For example, the Determinants School focused only on the initial idea generation/screening stage of NPD and asserted that this is the most effective way to improve new product performance (e.g., Cooper, 1979, 1981, 1982; Baker et al., 1986; Calantone et al., 1993). Most scholars treated NPD as a single activity, as a whole, but failed to consider the dynamics of the process (e.g., Allen, 1970; Hall and Ritchie, 1975; Myers, 1983; Sullo et al., 1985; Bonnet, 1986; Hauptman, 1986; Nochur and Allen, 1992). Again, a static view of NPD fails to reflect the nature of real-world product innovation.

A Closed-System Perspective

Although it is widely accepted that any social system cannot be insulated from the influences of its external world, many NPD researchers still see product innovation as a closed-system that can be analysed alone without considering the impact of environmental dynamics (e.g., Grady and Fincham, 1990; Peters, 1990, 1991; Nonaka, 1990, 1991). They have tended to investigate NPD practices within narrow and definitive environmental situations/conditions while assuming the general applicability of their findings to all NPD situations. However, it is clear that NPD is an open system which is more or less conditioned by its external and internal environment. It is also true that different types of NPD may encounter different limitations/opportunities imposed by the external and internal environment. Such limitations/opportunities for a specific type of NPD are also changing with time. Arguably, it is hard to procure a "general model" for managing all types of NPD project. The deployment of managerial efforts for any NPD type should be contingent upon the requirements imposed by its environment. A contingency approach to research in this field may be considered more appropriate if the research findings are to provide practical guidelines for real-world product innovation.

§1.5 Objectives of the Current Research

The current study concentrates on information processing and knowledge accumulation as the driving force in effective NPD management. Meanwhile, NPD is treated as an open, integrated, and dynamic system that is conditioned by its incumbent external and internal world, on the one hand, and as tasks conducted during the process which are coherent and continuous and cannot be easily separated from each other, on the other. The contingent management of information and knowledge, thereby achieving the appropriate balance of loose and tight control between corporate and project-level, is one of the most significant activities in NPD management. A key question is the extent to which a firm should shape its structure and strategy to suit a particular NPD. Is it beneficial for firms to tailor their new product development strategies to accommodate different project situations and conditions? If the answer is yes, what is the underlying structure of NPD dynamics? How do NPD managers adapt a NPD project, given that its specific needs and requirements are contingent upon the new product situations? The objectives of the research are:

(1) to investigate the underlying structure of NPD dynamics, so as to differentiate the nature of NPD situations/conditions, and

(2) to examine whether the management of NPD information processing and knowledge accumulation are contingent upon such NPD situations/conditions.

§1.6 Strategy, Method, and Scope of the Study

To fulfil the above research objectives, the current study intends to examine successful industrial experiences of product innovation management based on real-world observations. The basic unit of analysis is the NPD project, which is defined as a new product that was developed and commercialized during the last five years and was not previously manufactured by the firm. The major concern about the innovation activities is new product development, rather than the basic or applied research undertaken. The current study also intends to acquire a data set that contains highly heterogeneous cases so as to examine the contingency hypothesis. Another concern is the accessibility of the research population. The population should be accessible to the researcher with an acceptable response rate. The researcher should be able to communicate with the sample firms freely so as to avoid unnecessary guesswork in interpreting the qualitative information acquired from fieldwork. Based on these considerations, the current study selected Taiwan, the researcher's home country, as the focal area for conducting fieldwork.

Taiwan is a small island that is scarce in mineral resources. The only source for supporting its economic growth and gathering national wealth is its labour force. It was once a very poor country in terms of both capital and technology; the major sources of GNP were from agriculture and labour-intensive production. Nevertheless, by benefiting from its great success in education, technology-intensive production started to dominate its total exports. In 45 years, Taiwan has grown from extreme poverty to a certain level of richness (with the world's second largest foreign exchange reserves in 1994); meanwhile, many Taiwanese firms have also transformed from labour-based producers to knowledge-based producers. The change has been significant and achieved within a relatively short time. Thus, Taiwanese NPD cases provide the necessary heterogeneity for the current study. Examples ranging from traditional agricultural products to highly industrialised products, from very low cost imitations and incremental innovations to radical breakthroughs, can be found in Taiwan's domestic market. Consequently, this also provides a great opportunity for the researcher to study a wide range of R&D activities.

Over the years, although the total amount of Taiwan's annual national R&D expenditure has increased exponentially, the proportion of R&D funds allocated to different types of research has remained constant. For example, in 1991 about 11.5% of the funds were spent in Basic Research, while 40.3% and 48.2% were used in Applied Research and Experimental Development respectively. This reflects the national focus of Taiwan's R&D, in which down-stream development applications are far more important than up-stream basic research. Furthermore, government and research institutes/ universities bear the responsibility for most basic and applied researches, leaving Taiwanese firms to focus on the "development" side of R&D. As the managerial requirements for "scientific research" and "product development" may be different, the observation of new product development activities may be distorted if scientific research is also the major issue in firms' R&D. The Taiwanese cases provide a great opportunity for the current study to concentrate on NPD activities without concerning itself about the possible influences caused by factors of "scientific research".

Research variables were identified through a comprehensive literature review as well as an exploratory study aimed at providing initial knowledge about the research domain. By using representative sampling design, in-depth interview techniques, and a set of quantitative research instruments, both qualitative and quantitative data were acquired. Furthermore, to ensure the validity of using inference statistic methods in the analyses, the normality of research data was also considered in the research design. Chapter Four more fully discusses the research scope and research methodology for the current study.

§1.7 Organisation of the Thesis

The thesis is organised into eleven chapters. A comprehensive literature review consisting of more than 350 major articles and books on innovation management is provided in Chapter Two. A general model for managing product innovation is developed. This helps to organize the huge amount of literature on the topic to date, while providing a typology of different research approaches conducted in the field of NPD management. The nature of new product development and the key variables in managing new product development are discussed, these forming the basis of the current research framework.

The development and rationalisation of the current research framework are presented in Chapter Three. Based on previous academic work, the current study constructs propositions and hypotheses relating to the contingent approach to managing information processing and knowledge accumulation during NPD.

Chapter Four describes the scope and methodologies used for examining the research propositions and hypotheses. With reference to the research framework, this chapter discusses the rationale for the research approach adopted, sampling design, and statistical methodologies. The reliability and validity of the current research design are examined based on the research data. How and to what extent the research data can be used to test the hypotheses are discussed. This is important because only validated data and research design can produce valid research findings. The limitations of the research design are also discussed.

Chapter Five gives general profiles of the focal population and research samples. The underlying structure of NPD dynamics are examined, which provides a better observation of NPD contingent situations/conditions. Both external and internal contingency factors are identified and examined through the use of multivariate techniques.

Chapters Six to Nine cover the main body of empirical analyses. These include investigations into contingency management of NPD information acquisition, information transmission, knowledge creation/accumulation, and organisational deployment to facilitate NPD information/knowledge management. Statistical evidence is presented to support or reject study hypotheses.

Chapter Ten provides eleven case studies in an attempt to provide in-depth perspectives on real-world NPD. Insights drawn from these case studies are compared with the statistical results presented in previous chapters. This provides a means by which to validate and rationalize the quantitative findings.

General findings of the current study are summarized in Chapter Eleven, where the results are discussed in the light of relevant literature. The implications and limitations of these findings as well as directions for future research are also discussed.

Research instruments, the qualitative interview structure, a list of sample firms, correspondence relating to the research, and a brief description of the software incentive for increasing response rate are provided in the appendices.

Chapter Two

Theoretical Foundations of Product Innovation Researches

2

This chapter reviews previous works concerned with new product development as well as the conceptual framework of the current study. It will firstly start with an in-depth discussion about the nature of new product development and the managerial objectives of NPD, and then construct a general framework for investigating the motives of previous researches on this subject. Several approaches or schools of thought were identified and examined. Although previous studies contributed much to our understanding of firms' NPD behaviour, as researchers tend to concentrate on their particular research interests, each approach more or less encountered additional constraints imposed by time, methodology, selection of research variables or access to information. This provides opportunities for the current study. This chapter asserts that the concept of "fit" may be more than appropriate to reveal the reality of NPD management.

2 Theoretical Foundations of Product Innovation Researches

§2.1 Introduction

The very early studies into innovation mainly evolved around the concepts of Economics which focused on how innovation improves the individual firm's competitiveness and accelerates national welfare, rather than on innovation management itself (Stoneman, 1983: 2-3). For example, Schumpeterism, which emerged in the late 1930s, stressed the role of innovation in firm competitiveness, in the evolution of industrial structures, and in processes of new regulations and procedures in the economic system (Schumpeter, 1939, 1942). Successive economists researching into innovation focused their efforts on correlating technological progress with national economic growth either exogenously (Solow, 1957, 1970; Abramovitz, 1956; Kendrick, 1973) or endogenously (Arrow, 1962; Levhari, 1966; Sheshinski, 1967; King and Robson, 1989; Romer, 1986, 1990). The higher the level of national R&D expenditure, the stronger the economic growth of the society.

Based on the above assertions, industrial growth as well as corporate competitiveness are both influenced by the efforts of innovation (Porter, 1990). The theories of technology life cycle (e.g., the well-known proposition of S-curve) were thus developed so as to forecast the growth path of a specific technology or industry. Successful companies were believed to have high R&D expenditures (Bergen and Miyajima, 1986), to be knowledgeable of the dynamics of competition, and to be proficient in adapting to the trend of technological progress (Foster, 1986). These studies have contributed much to our understanding of the nature of technological innovation and meanwhile have improved the quality of national industrial policy. However, they have little to do with firm-level innovation management.

Studies of practical innovation management at the firm level did not gain much attention until after the 1950s. However, since then, a vast amount of studies has been concentrated on the investigation of new product development (NPD) activities. While these previous academic efforts have contributed greatly to the main body of knowledge about innovation management, the foci of, or research approaches used by, these researchers were highly diversified (Kelly and Kranzberg, 1978). This leads to a somewhat ambiguous situation for the practitioners as well as the researchers: in some areas these studies resulted in similar conclusions for better innovation management while in other areas they did not.

To clarify the nature of NPD management, this chapter provides an in-depth review of relevant literature. The following are the major concerns in the literature review.

(1) Why should new product development be managed?

(2) What are the main issues in NPD management?

(3) What approaches were used by early researches to cope with these issues of NPD management?

(4) To what extent have previous approaches provided sufficient guidelines for managing NPD?

This chapter will first present a brief description of the historical developments in innovation management studies (Section 2.2). These early efforts provided insight into what innovation management is, and why it matters. In Section 2.3, the current study further proposes a basic framework of NPD management, in which three broad streams of thought about product innovation are identified, namely, (1) the Determinants School studies, (2) the Systematic School studies, and (3) the Design School studies. Sections 2.4 to 2.6 discuss these schools of thought in detail. Section 2.7 summarises the research approaches discussed in this chapter and further suggests that a more integrated model of product innovation is necessary, so as to extend the frontier of current knowledge about effective NPD management.

§2.2 A Brief History of Innovation Studies[1]

Schumpeter (1939) was possibly the most influential author who stressed the importance of innovation to the firm. However, Gilfillan (1935) may have been the first to observe and describe innovation activities at the firm level. Gilfillan illustrated innovation as a continuous and cumulative process at the laboratory, that any invention stemmed from a series of scientific developments in its specific research area. Immediately afterwards, Wright (1936) announced his well-known "20%" learning curve rule. He proposed that every doubling of cumulated output will result in a reduction of 20% in average cost. The subsequent empirical evidence for "learning by doing" theory (e.g., Hirsch, 1952, 1956; Hollander, 1965; Baloff, 1966) therefore favoured the large firms' monopoly position which benefited greatly from learning effects.

The Schumpeterian extended the above observations and asserted that large and monopolistic firms were more capable than small ones in accumulating sufficient knowledge so as to implement innovation. Such innovation, in turn, will enhance the monopoly power of the firm (Mansfield, 1968). While the 1930s was the age when economists recognized the importance of innovation, it was in the 1950s and 1960s that scholars started to establish the foundations for R&D management research. Inspired by traditional Schumpeterism, the concept of innovation embraced by the early studies mainly referred to scientific work in large centralised laboratories. Many researchers concentrated on the management of scientific laboratories which were assumed to be closed systems, totally isolated from the outside world. These research interests include:

(1) project management techniques such as parallel scheduling and outsourcing (Schlaifer, 1950; Klein, 1963; Marschak, 1963; Allen, 1966a),

(2) laboratory supervision and organisational development (Burns and Stalker, 1961; Pelz and Andrews, 1966; Andrews and Farris, 1967),

(3) project idea generation within the research laboratory (Rubenstein and Hannenberg, 1965; Baker et al., 1967),

(4) investigation of product innovation as a "Technology-push" process (Carter and Williams, 1956; Gruber and Marquis, 1969), and

(5) information seeking and transmission patterns among technical personnel (Hagstrom, 1965; Allen, 1966b; Rosenbloom and Wolek, 1967; Gertsberger and Allen, 1968; Allen and Cohen, 1969).

In these early days the notion of industrial technological innovation was generally theorised as a linear process beginning with scientific discovery/invention, progressing to in-house research and development, engineering and manufacturing activities, and ending with a marketable new product or service which fulfils the economic use of technical knowledge (Carter and Williams, 1956). The emphasis on the role of technology stimulated a series of studies into laboratory R&D

management (e.g., Allen, 1970; Evans et al., 1974). Many scholars used the term "technology-push" to describe such a technology-oriented view of NPD (e.g., Grady and Fincham, 1990; Rothwell and Whiston, 1990; Rothwell, 1992; Brockhoff and Pearson, 1992). In their view, the management of information acquisition and communication within research laboratories, in essence, is the core task of innovation management.

Such "technology-push" continued to dominate the thought of innovation management until about the mid to late 1960s when more empirical studies based on real world practices began to be published. Having been influenced by the revolutionary idea of "Marketing Myopia" (Levitt, 1960), during the late 1960s to early 1970s, innovation studies finally acknowledged the importance of the marketplace. A new stream of thinking was emerging, assuming a "market-pull" innovation process that started from consumer needs through closely focused R&D activities, and led to more customer-oriented new products (Myers and Marquis, 1969). Several studies concluded that most new product failures were due to poor marketing rather than technological weaknesses (Booz, Allen and Hamilton, Inc., 1968; Gerstenfeld et al., 1969; Myers and Marquis 1969). In another major study of 567 innovations, Marquis (1969) found that three quarters of projects were eventually triggered by market needs. The nature of the innovation process therefore was seen as fundamentally determined by market forces (Myers and Marquis, 1969; Roberts, 1969). The understanding of market trends, customer needs, and competitive situation are the key elements of successful NPD implementation.

However, during the 1970s, both the "technology-push" and the "market-pull" view of the innovation process were widely challenged. Rothwell (1972) and Rothwell et al. (1974) in their pioneering Project SAPPHO suggested a more general process of coupling between science/technology and marketplace/customer. Subsequently, New (1979), Twiss (1980), Sommers (1982), and Cooper (1983c) also highlighted the necessity of a more balanced approach in managing R&D. To do this, proficiency in managing multi-functional coupling is essential. Many scholars suggested mechanisms for fostering information transmission within and between functional departments (e.g., Taylor and Utterback, 1975; Pruthi and Nagpaul, 1978; Bonnet, 1986; Souder, 1987; Gupta and Wilemon, 1988; Song and Parry, 1993; Moenaert et al., 1994).

The essence of innovation management therefore became a multi-facet and multi-discipline system of information transmission and decision making. R&D management, to some extent, can be seen as the management of the information system. The core within this system is the communication network within the community of scientists and engineers, with the entire innovation process being configured and adapted according to internal core competencies and the vagaries of the outside environment.

The next section takes a step forward to present a basic framework of NPD management, based on the observation of technological innovation from these early studies. This framework will therefore be used as a general structure for guiding a review of the main body of literature.

§2.3 The Basic Framework for Researching NPD Management

Organisational studies and strategic management researches often highlighted the role of management in fulfilling corporate strategic goals, based on the understanding of the incumbent environment (e.g., Chandler, 1962; Miles and Snow, 1984; Mintzberg et al., 1988). Researchers in innovation management also stressed the strategic fit between NPD managerial practices and environmental dynamics as an important factor influencing project outcome (e.g., Kast and Rosenzweig, 1972; Gupta et al., 1986; Capon et al., 1992; Bryson and Bromiley, 1993; Shenhar, 1993). Managerial excellence in NPD is largely dependent upon the flexibility and efficiency of firms in observing and matching their environment and in implementing the corresponding NPD strategies. As observed by Miles and Snow (1984: 10),

> *Successful organizations achieve strategic fit with their market environment and support their strategies with appropriately designed structures and management processes. Less successful organizations typically exhibit poor fit externally and/or internally.*

From this point of view, three major areas of research interest can be found in NPD management studies: (1) the effective implementation of NPD management, (2) the consideration of managerial uncertainty imposed by the environmental dynamics, and (3) the measures of project outcome.

2.3.1 *The Effective Implementation of NPD management*

The Concept of New Product

The Schumpeterians were perhaps the first to distinguish the differences among various types of innovation, e.g., product innovation, process innovation, and organisational innovation. However, these early definitions did not clarify the differences between invention and innovation. Mohr (1969) differentiated innovation from invention. He stated that invention is a series of research activities leading to a physical item that is new to the organisation: innovation is the real-world application of such invention. Meanwhile, Ansoff and Stewart (1967) also pointed out that the term R&D in its own right suggests both "research" and "development" type activities. Hence firms with different levels of proficiency in these two types of activity can be divided into R-intensive and D-intensive organisational settings. In this sense, inventions may be regarded as the scientific research efforts which are aimed at producing technical solutions. Innovation therefore is the development process which finally brings marketable new products. In conclusion, Allen et al. (1980) suggested that R&D activities can be distinguished into: (1) Basic Research (2) Applied Research (3) Development (4) Technical Service.

These early discussions more or less assumed that the only dimension in defining new product type is the newness of the technology employed. New products were thus classified into two extremes, i.e., either technologically radical or technologically incremental (Ettlie et al. 1984; Dewar and Dutton 1986; Harrison and Hart, 1987; Khan and Manopichetwattana, 1989; Nilakanta and Scamell, 1990; Kodama, 1992). Other scholars also added more specifications derived from the same root of classification between these two extremes (Piatier, 1984: 94-97; Ansoff, 1987; Watts and Higgins, 1987; Abetti and Stuart, 1988; Gardiner and Rothwell, 1989; Dwyer, 1990; Dwyer and Mellor, 1991; Shenhar, 1993). For example, Gardiner and Rothwell (1989: 170-183) listed the following new product types and suggested that in real-world situations about 90% of new products are merely incremental design changes and only 10% are radically new. Their classifications are:

(1) Larger Design Steps:

- Landmark Innovations
- Radical Innovations
- Major Innovations

(2) Smaller Design Steps:

- Incremental Innovations
- Generational Innovations
- New Mark Numbers (Product Redesign)
- Improvement Innovations
- Minor Detailed Innovations.

In addition, the above concept of technology as a dimension to classify new product type was sometimes joined with another dimension of consideration, i.e., the product itself. To some extent product specifications/functions are inseparable from the technology employed in producing it. Ansoff (1987)'s classification of "Cosmetics", "Performance Improvement", "Redesign", and "New Technology" is an example that combined both technology and product dimensions to describe the novelty of new products (also see Particelli and Killips, 1986; Bart, 1993). Wheelwright and Sasser (1989) went even further to provide a more complete and systematic view of new product type in terms of "product" dimension. By identifying the relationship between firms' core technologies and their subsequent products, they presented a systematic framework to classify new product types:

(1) Development Work (i.e., concept/functional prototypes),
(2) Engineering Prototype,
(3) Core Products (refined from initial prototypes),
(4) Enhanced Products,
(5) Customized Products,
(6) Cost-reduced Products, and
(7) Hybrid Products (which merge characteristics from two core products).

However, with the awakening of the marketing concept around 1960, other scholars considered more dimensions in differentiating new product type. Besides "technological newness", Ansoff (1957) and Johnson and Jones (1957) were among the first to incorporate "market newness" as another dimension for categorizing new products. By arraying the "product objectives" in these two dimensions, Johnson and Jones were able to identify eight different types of new products, namely,

- Remerchandising,
- Reformulation,
- Improved Product,
- New Use,
- Replacement,
- Market Extension,
- Product Line Extension, and
- Diversification.

In a similar manner, More (1978), Maidique and Zirger (1984), Meyer and Roberts (1986), Particelli and Killips (1986), and Abetti and Stuart (1988) all considered new product newness to be a reflection of the match between technological competence and market needs.

Another well-recognized dimension for categorizing new products is the familiarity of the product to the firm (Bart, 1993: 190). Indeed, a new product is meaningful only if it is new to the company (Johnson and Jones, 1957: 52). Perhaps the most frequently used measurement of product familiarity is a comparison of the new product with the existing product range of the firm. Therefore, a "product-line extension" may be regarded as less novel product while a "totally new product-line" has a higher novelty status (Johnson and Jones, 1957; Cooper, 1979, 1981, 1983b, 1984, 1985; Cooper and Kleinschmidt, 1990; Dwyer, 1990; Dwyer and Mellor, 1991; Rochford and Rudelius, 1992). However, some scholars preferred other measurements for familiarity. For example, the routineness or nonroutineness of the NPD project may be another indicator for measuring familiarity (Fischer, 1979; Keller, 1994). In addition, Keller (1994) suggested that "analysability" of the NPD project may also be used as an indicator.

In some cases new product type was also distinguished in terms of customers' point of view. For example, Robinson (1990: 1283) defined incremental new product by using the following statement:

Table 2.1 Dimensions of New Product Type

Sources	Technology Dimension	Product Dimension	Market Dimension	Customer Dimension	Firm Dimension
Abetti and Stuart (1988)	✔		✔		
Allen, Lee, and Tushman (1980)	✔				
Ansoff (1987)	✔				
Bart (1993)	✔	✔			✔
Cooper (1979, 1981, 1983b, 1984, 1985)	✔	✔	✔	✔	✔
Cooper and Kleinschmidt (1990)	✔	✔	✔	✔	✔
Dewar and Dutton (1986)	✔				
Dwyer (1990)	✔				✔
Dwyer and Mellor (1991)	✔				✔
Ettlie et al. (1984)	✔				
Fischer (1979)					✔
Harrison and Hart (1987)	✔				
Johnson and Jones (1957)	✔		✔		✔
Keller (1994)					✔
Khan and Manopichetwattana (1989)	✔				
Kodama (1992)	✔				
Madique and Zirger (1984)	✔				
Meyer and Roberts (1986)	✔		✔		
Nilakanta and Scamell (1990)	✔				
Particelli and Killips (1986)	✔	✔	✔		
Robinson (1990)				✔	
Rochford and Rudelius (1992)			✔	✔	✔
Rothwell (1992)	✔				
Shenhar (1993)	✔				
Watts and Higgins (1987)	✔				
Wheelwright and Sasser (1989)		✔			

These products or services attempted to meet customer needs already being served by existing products, but they met those needs with a new technology or method ... [or] using basically the same technology and methods.

Cooper (1979, 1981, 1983b, 1984, 1985), Cooper and Kleinschmidt (1990), and Rochford (1991) were also very keen on applying customer orientation in defining new product type. In their definition, "newness" is the degree of net benefit that the product can provide to its customers. However, in real-world situations it is somewhat difficult for researchers to measure objectively the "net benefit" that customers can perceive. Researchers used this dimension to measure new product newness through the perception of firms, rather than from the perception of customers themselves.

In sum, this section has identified five dimensions for distinguishing new product type, i.e., the technology dimension, the product dimension, the market dimension, *the customer* dimension, and the firm dimension (Table 2.1). However, most scholars tended to choose subjectively one or two dimensions from the complexity without bothering how exactly firms view new products. From an industrial perspective, there is no one definition for a new product used by all firms.

The Nature of New Product Development Management

Around the 1960s NPD was often viewed as a linear process of transferring scientific knowledge into marketable products (Carter and Williams, 1956). The key issues in NPD management therefore emphasized supervision of scientists/engineers (Burns and Stalker, 1961; Pelz and Andrews, 1966; Andrews and Farris, 1967) and efficient project control (Schlaifer, 1950; Klein, 1963; Marschak, 1963; Allen, 1966a). T.J. Allen and his colleagues from MIT as well as others were at that time starting to investigate technical communication patterns within scientific laboratories (Hagstrom, 1965; Allen, 1966b; Rosenbloom and Wolek, 1967; Gertsberger and Allen, 1968; Allen and Cohen, 1969; Allen, 1970; Frost and Whitley, 1971; Evans et al., 1974; Allen and Fustfeld, 1975; Hall and Ritchie, 1975; Dewhirst et al., 1978). NPD management to some extent was synonymous with the management of the scientists/engineers, technological communications being regarded as the engine of innovation. The central focus of R&D management was to facilitate NPD by harnessing the firm's technological capability and, therefore, fulfil corporate competitive strategy (Freeman, 1965). The fulfilment of customer needs, however, was rarely considered.

Another stream of thought emerging after the 1960s regarded NPD as a reflection of customer needs (Marquis, 1969; Myers and Marquis, 1969; Roberts, 1969; Gerstenfeld, 1976). The NPD process was likened to an information system which converts consumer information into product ideas and product designs, and in turn, satisfies customer needs. The interfaces between producer and customers are essential. The core of NPD management was to master the information transmission mechanism between these two sides. Other researchers who emphasized the customer-oriented concept also maintained that the quality of customer-based information was critical to new product success (Aram and Javian, 1973; Souder and Chakrabarti, 1978). Especially in the early stages of a development cycle the involvement of marketing function is required to reduce project uncertainty (New, 1979). Successful companies often *flexibly adapt* their marketing information acquisition strategy to NPD dynamics so as to better facilitate product innovation (More, 1978).

In summary, the 1960s and the 1970s' view of NPD heavily emphasized the process of information acquisition, transmission, and utilisation. As Goldhar et al. (1976: 52) suggested:

> *From a behavioral point of view, technological change and innovation occur as the result of complex sets of human interactions, information flows and transfers, individual and organizational creativity, and individual and organizational risk-taking and decision-making . . .*

The 1980s saw proliferation in NPD research. In the first half of the decade, R.G. Cooper from Canada was the first to employ an extensive range of research variables, large sample size, and multivariate techniques in the investigation of NPD. He treated NPD management as a "black box" and directly correlated the new product's characteristics with its commercialisation performance (Cooper, 1979, 1981, 1983b, 1984, 1985; Cooper and Kleinschmidt, 1990), although in his later work he has recognized the potential drawback of such an approach and tried to promote a Stage-Gate NPD process model, instead of the "black box", as an universal means for managing NPD (Cooper, 1988, 1990; Cooper and Kleinschmidt, 1988, 1991). However, the essence of his NPD research was project screening rather than NPD management.

Another important angle of R&D management emerging from the 1980s was the emphasis on managing departmental interfaces during NPD (Souder and Chakrabarti, 1978; Bergen, 1982; Burt and Soukup, 1985; Gupta et al., 1985, 1986; Bergen and Miyajima, 1986; Bonnet, 1986; Souder, 1987; Brockhoff and Chakrabarti, 1988; Gupta, 1990; van Dierdonck, 1990; Carlsson, 1991; Song and Parry, 1992, 1993; Calantone et al., 1993). This stream of thought was mainly rooted in the concept that R&D is the match of technology competence of the firm and the consumer needs in the marketplace. They regarded the whole NPD process as simply the management of coupling between different functional areas. Successful NPD are those which can harmonize the conflict between different disciplines, especially R&D and Marketing.

Effective communication and information transmission between disciplines therefore was regarded as the main issue in managing R&D (Bush, 1991; Good, 1991; Griffin and Hauser, 1992).

In the meantime, stimulated by the rise in Japanese economic power, scholars in the late 1980s and early 1990s started rethinking the value of western style management practices. Many researches were undertaken, in an attempt to reveal the secret of Japanese innovation excellence (Takeuchi and Nonaka, 1986; Clark et al., 1987; Speiser, 1988; Clark, 1989; Roberts and Mizouchi, 1989; Clark and Fujimoto, 1990, 1991ab; Ealey and Soderberg, 1990; Nonaka, 1990, 1991; Bowonder and Miyake, 1992; Fukasaku, 1992; Kodama, 1992; Bolton, 1993; Collinson, 1993; Dyer and Ouchi, 1993; Samuels, 1994). These studies suggested that Japanese technological competence is a result of corporate-wide learning, improving, and mastering of both product and process innovation. Japanese firms used to employ multi-discipline teams, with people from production, marketing and the suppliers working together with R&D, for new product development. In-service training and job-rotation are regular, for facilitating the sharing and spreading of information.

In probing into Japanese experiences, western researchers finally recognised that the essence of these successful recipes in effect was the thorough implementation of long-ignored western organisational learning theory (Bowonder and Miyake, 1992; Ghoshal and Bulter, 1992; Jones, 1992; Bolton, 1993; Garvin, 1993). Scholars therefore highlighted the role of learning in NPD. As stated by de Meyer (1993: 44):

> *Learning is the process within the organization by which knowledge about action-outcome relationships and the effects of the environment on these relationships is developed. The outcome of the learning process is knowledge that is distributed across the organization, is communicable among members, has consensual validity, and is integrated into the working procedures of the organization.*

Such conceptualisation from learning theory was later extended to the studies of knowledge management in Japanese companies. In addition to the focus on knowledge creation, knowledge internalisation and knowledge accumulation were also highlighted as the key to successful R&D management. Moreover, as organisational learning theory also suggested a double loop mechanism which examines the validity of knowledge itself (i.e., theory of action) (Argyris, 1977), NPD was also regarded as an intelligent learning system which accumulates and filters internal and external information, while assimilating and processing it into high quality knowledge.

This section briefly reviewed the theoretical development of R&D management, in an attempt to express the evolutionary nature of NPD studies. Taking a relatively narrow perspective, NPD could be regarded as a system for managing project-related communications within research laboratories. A wider viewpoint sees NPD as a corporate-wide learning process, where multi-discipline knowledge is created, cumulated, and shared between functional departments. Indeed, the effective management of product innovation is the recognition of the value of information and knowledge. Proficiency in filtering data into information, assimilating information into knowledge, and using this knowledge to direct NPD efforts, are the basic ingredients for successful NPD implementation.

2.3.2 Environmental Dynamics in NPD Management

Literature often suggested that uncertainty imposed by the environmental dynamics is the key characteristic of R&D management (Abernathy, 1971; Holland et al., 1976; Maidique and Hayes, 1984; Bonnet, 1986; Batson, 1987; Clark et al., 1987; Abetti and Stuart, Rogers, 1982; 1988; Bienayme, 1988; Bodensteiner, 1989; Pavitt et al., 1989: 64; van der Meer and Calori, 1989; Hall and Nauda, 1990; Pavitt, 1990; Iya and Akhilesh, 1992). Except for van de Ven (1986) who argued that uncertainty in R&D should be welcomed because it provides the necessary stimulus for invention, most scholars concentrated their interest on reducing NPD uncertainty (Holland et al., 1976; Bozeman and McGowan, 1982: 150; Rogers, 1982; Sullo, 1982; Gupta et al., 1986; Bienayme, 1988: 576; Batson, 1987; Moenaert and Souder, 1990; Bolton, 1993).

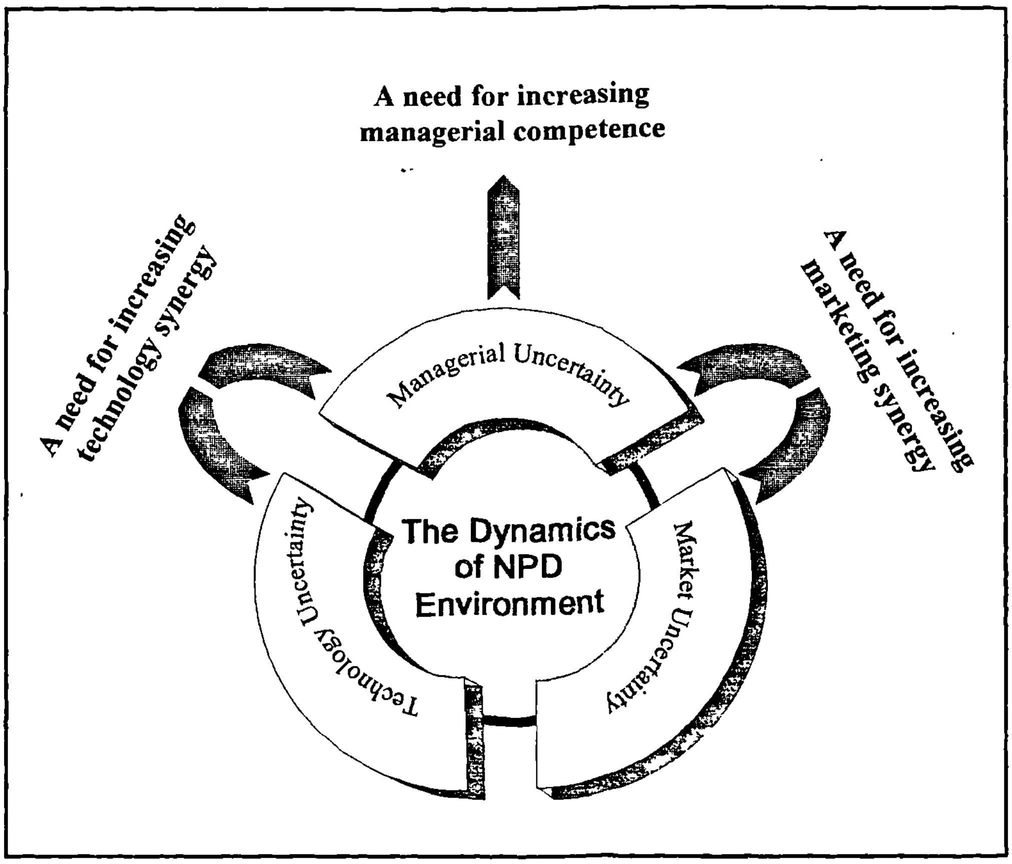
Such uncertainty in NPD can be seen as three-fold: technological uncertainty, market uncertainty, and managerial uncertainty. Technological uncertainty results from the discontinuity (Foster, 1986) and the increasing complexity (Rogers, 1982; Bonnet, 1986; Shenhar, 1993) of scientific/technological developments and their commercial applications in the marketplace. Market uncertainty comes from the incompleteness of information about counterparts' competitive behaviour (Brockhoff and Chakrabarti, 1988) and the future market outcome of finished products (More, 1984; Bonnet, 1986). Finally, managerial uncertainty is rooted in the unfamiliarity of the firm with the new product class, e.g., nonroutine projects (Keller, 1994). To deal with these three types of uncertainty, a firm should adapt itself to match with three different sets of environment variables (see Figure 2.1):

(1) development of managerial proficiency in both NPD management skill and engineering/production capability,

(2) the fit between managerial competence and marketplace/customer needs (i.e., marketing synergy), and

(3) the fit between managerial competence and technology (i.e., technology synergy).

Figure 2.1 The Dynamics of NPD Environment



Source: The Current Study

There are many ways of coping with the above three sets of environment variables. However, the most frequently mentioned approach may be that of better mastering and facilitating information acquisition and transmission (Bozeman and McGowan, 1982; Rogers, 1982; Sullo et al., 1985; Batson, 1987; Moenaert and Souder, 1990). As suggested by Daft and Weick (1984: 285) from the organisational information processing school of thought:

> *... organizations are open social systems that process information from the environment. The environment contains some level of uncertainty, so the organization must seek information and then base organizational action on that information.*

These information processing arrangements include inter-organisational (Bozeman and McGowan, 1982; Sullo et al., 1985) and intra-organisational (Sullo et al., 1985; Gupta et al., 1986; Moenaert and Souder, 1990) communication and integration. A close link of the firm with its customers, distributors, and suppliers as well as an effectively managed coupling of functions within the firm are important in reducing NPD uncertainty. The preservation of flexibility for organisational restructuring is needed for smoothing the above processes (Bienayme, 1988: 576).

2.3.3 Measures of NPD Performance

Previous researchers have used a variety of approaches to measure NPD performance. In firm-level innovation studies, NPD performance often denotes the overall innovativeness of the firm, or the degree of dependence of the firm upon innovation. For example, "Number of launches resulting from new product development projects in last five years" (Hart and Service, 1988) in essence was examining the willingness of the firm to develop new products and its capability of doing so. Other similar indicators include "number of NPD projects in last five years" (Hart, 1993), "number of patents granted" (Chakrabarti, 1991), and "new product success rates" (Cooper, 1984; Hart and Service, 1988). On the other hand, the measures of the impact of new products upon corporate "market share", "profit margin", or "turnover growth" (e.g., Bonnet, 1986) mainly focus on presenting the impact of NPD upon firms, rather than the measure of innovation itself.

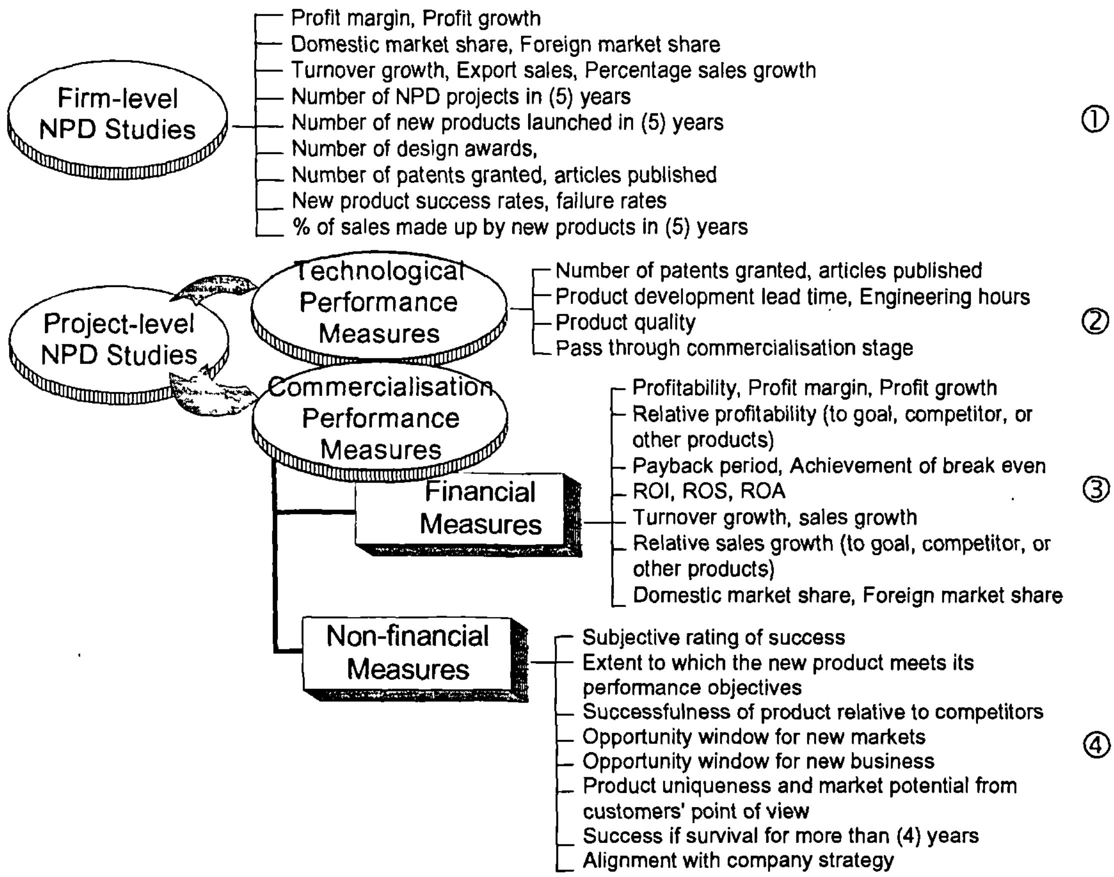
In the project-level studies, NPD performance was actually measured in terms of project outcomes. Such project outcomes, due to a variety of research interests among scholars, may be measured in several different ways. The first level of differences results from the scope of research undertaken or the assumed nature of NPD. While NPD is regarded as a technological process which transforms scientific knowledge into tangible products, scholars often concentrate on technological indicators for measuring NPD performance. For example, "awards granted" (Goldhar et al., 1976), "project lead time" (Clark and Fujimoto, 1991ab), "engineering hours" (Clark and Fujimoto, 1991ab), "whether the project was killed before launch" (Cooper, 1982, 1984), were frequently cited. On the other hand, while NPD is viewed as one of the economic means that allies customer needs and corporations' competence, indicators concerning commercialisation performance tend to be more important. The latter type of indicator can further be distinguished into financial measures and non-financial measures.

Financial measures are aimed at identifying the contribution of a particular new product to the firm. Both possibilities exist, that the objective financial figures are directly used as performance indicators, or that the performance measures are subjectively estimated. The most frequently employed measures include: "profitability", "sales", "payback period", "ROI", and "market share" (e.g., Cooper, 1979, 1985; Cooper and Kleinschmidt, 1987abc). Non-financial measures are often the subjective rating of new product success (or failure). Those questioned may be asked to rate how successful the product was in terms of his/her own judgement (Cooper, 1984). Other indicators are also frequently used, such as: "measure of success with which the new product meets its performance objectives", "successfulness of product relative to competitors" (Cooper, 1984), or "product uniqueness and market potential from customers' point of view", "opportunity window on new market" (Cooper and Kleinschmidt, 1987abc). Figure 2.2 is a summary of structure and possible indicators for measuring NPD performance.

Hart (1993) in her comprehensive literature review and empirical examination of the validity of performance indicators concluded that financial measures such as sales growth or profit margin may be inadequate in measuring NPD performance. This point of view agrees with that by Mechlin and Berg (1988: Ch.17) and Mitchell and Hamilton (1988), that financial measures in effect have definite limitations. On the other hand, the literature points out that, in practice, managers tend to use subjective judgement in dealing with corporate decisions (Packer, 1983; Brown and Svenson, 1988). Hence non-financial measures may be more useful in defining NPD performance (Brown and Gobeli, 1992). However, non-financial measures (especially the qualitative indicators) also have their particular drawbacks. As Brown and Gobeli (1992: 327) stated:

> *Qualitative measures suffer from being broadly suspect to many technically oriented persons (e.g., many R&D managers). Their primary concern is that because of the subjective nature of such measures, they are intrinsically unreliable.*

Figure 2.2 The Measures of NPD Performance



Sources: ① Cooper (1984); Cooper and Kleinschmidt (1987abc); Hart and Service (1988); Walsh et al. (1988). ② Goldhar et al. (1976); Nystrom (1985); Clark and Fujimoto (1991ab). ③ Cooper (1979, 1980, 1984); Calantone and Cooper (1981); Peters and Waterman (1982); Maidique and Zirger (1984); Cooper and Kleinschmidt (1987abc). ④ Rothwell et al. (1974); Cooper (1984); Canon (1984); Nystrom (1985); Voss (1985); Cooper and Kleinschmidt (1987abc); Ayal and Raban (1990).

Hart (1993) also claimed that indirect measures (e.g., sales growth vs. industry average) present a similar quality of direct measures (i.e., absolute financial figures). Therefore she suggested that indirect measures are preferable to direct ones because they can reduce the possible feeling of respondents about the data sensitivity (i.e., to increase response rate and data accuracy). Other suggestions that disfavour direct measures were also found in Cooper and Kleinschmidt (1987abc), Souder (1987), and Bart (1991, 1993) who suggest that absolute measures of performance were often biased towards the type of industry.

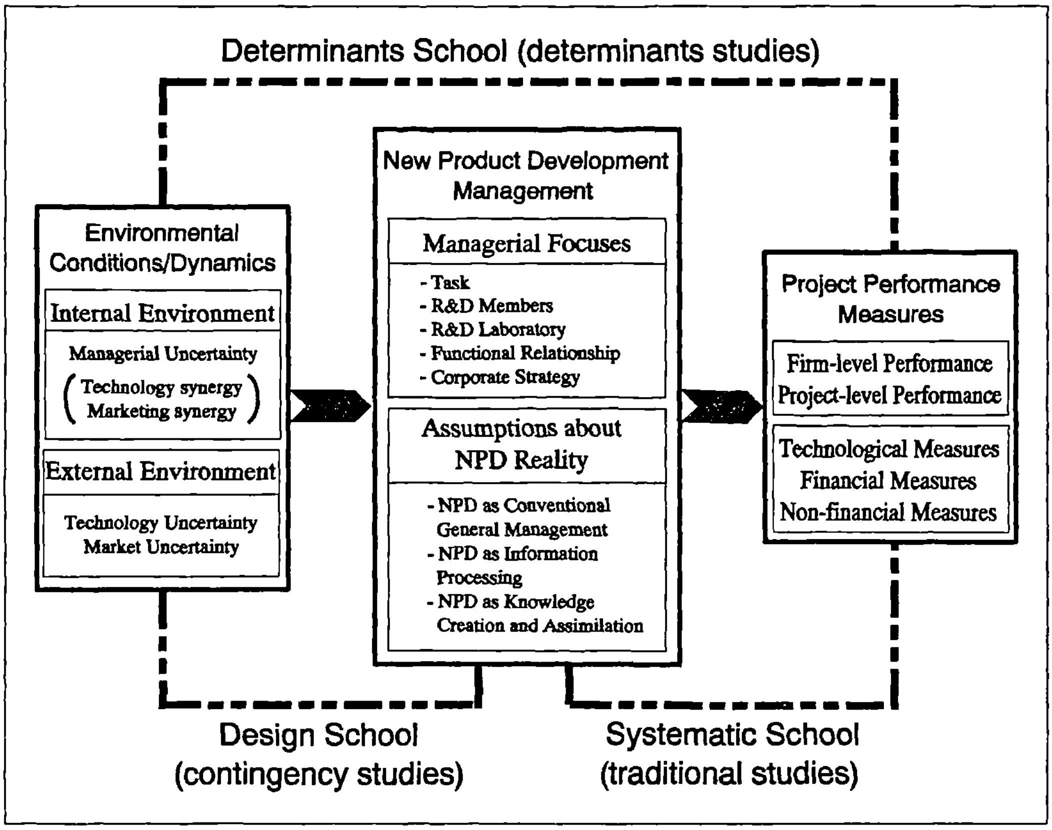
In sum, the non-financial measures, the indirect measures, and the Likert-type-scale measures (as opposed to absolute measures) were widely welcomed by previous researches. However, to get a more complete and reliable picture of NPD performance, researchers encourage the use of several different dimensions of indicators at a time, rather than just one (Souder, 1987; Brown and Gobeli, 1992).

2.3.4 Approaching an Organising Framework for NPD Literature

Based on the above discussions of three major areas of research interest, Figure 2.3 presents a basic framework/strategy for organising the literature review[3]. At the heart of the framework is that area of research concerning efforts involved in managing new product development. Two dimensions of thinking may be used to distinguish the variety of previous research focus, i.e., (1) consideration of managerial objectives in product innovation, and (2) assumptions about NPD reality. For the first dimension, these research objectives may include the management of single tasks, R&D members, the research laboratory, the relationships between the laboratory and other functional departments, and the corporate innovation strategy. For the second dimension, the essence of previous NPD studies may be seen as conventional general management, the management of information processing, or the management of NPD knowledge creation and assimilation.

The second part of the framework concerns the uncertainty in product innovation caused by environmental dynamics. The discussions in Section 2.3.2 suggest that three types of uncertainty can be found in product innovation, i.e., (1) technological uncertainty, (2) market

Figure 2.3 The Basic Framework of NPD Management



Source: the current study

uncertainty, and (3) managerial uncertainty. The first two sources of uncertainty are mostly resultant from the external world while the third one is from within the organisation. However, managerial uncertainty is in effect an echo of the former two. To achieve managerial proficiency the new product developer must deal with the synergy issues in terms of external technological progresses and market trends. It is closely related to the capability of firms to match technology with consumer needs.

The third part of the framework takes into account measures of project performance. Both firm-level and project-level measures may be used by previous researchers. These studies may also look into different performance indicators, such as technological measures, financial measures, or non-financial measures, to identify the outcome of managerial efforts in product innovation.

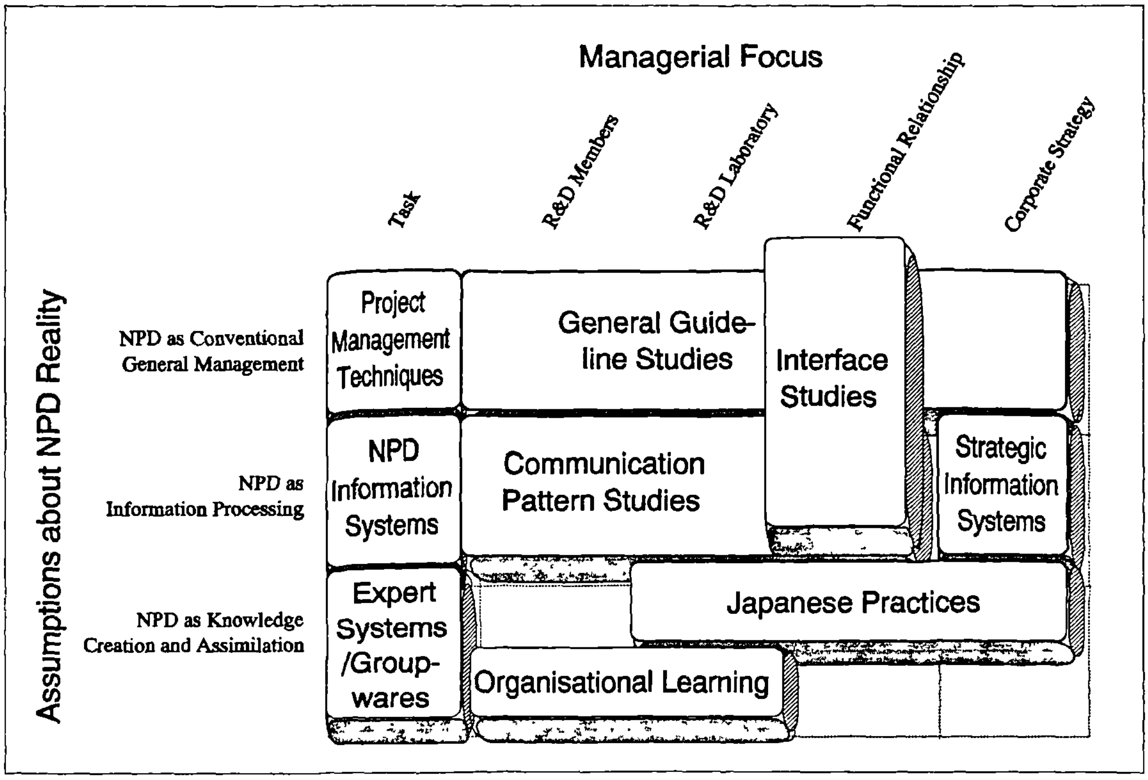
These three components of NPD research can be seen as logically correlated in a particular consequence. In fact, any effort in NPD management basically is a reflection of corporate strategies. On the one hand, these strategies to some extent must respond and adapt to the dynamics of external and internal environment. On the other, the effectiveness of such strategies in the end determines NPD project outcomes. Based on this framework, three main streams of work in NPD can be distinguished, namely, (1) the Determinants School studies (Section 2.4), (2) the Systematic School studies (Section 2.5), and (3) the Design School studies (Section 2.6)[2].

The Determinants School of thought treated NPD management as a black box and directly correlated final project performance with environmental conditions. It tended to assume a "black box" style innovation process; the main theme in NPD strategic formulation was the selection of a "suitable" project for the organisation, rather than the NPD management itself. It believed that the synergy of a project with the firm is essential to NPD success. The primary means to achieve successful product innovation lay in managers' and team players' ability to acquire a deep understanding of *prior hoc* internal and external project situations/conditions. A formal and rational pre-development screening process was regarded as highly necessary, to filter out the "bad" project ideas so as to insure the final project outcome.

Unlike the "fortune teller" style NPD management of the Determinants School approach, the Systematic School studies stressed the importance of using a systematic new product development process and implementation procedures. They believed that managerial factors play the main role in determining NPD performance and hence focused their research interest on investigating the actual NPD activities so as to identify the best model of NPD management. They argued that if, and only if, the whole process of NPD is well managed in a specific way, can successful commercialisation be achieved. According to the literature, most NPD studies fall under the Systematic School of thought. However, the definition of the "systematic view" of NPD management is highly varied depending upon the research assumptions and methodologies used by investigators and the managerial aims they pursue. The current research broadly categorises these Systematic School studies into the following (also see Figure 2.4):

(1) Generic Recipe Studies (Section 2.5.1),
(2) Communication Pattern Studies (Section 2.5.2),
(3) Interface Studies (Section 2.5.3),
(4) Japanese Practices (Section 2.5.4),
(5) Organisational Learning Studies (Section 2.5.5), and

Figure 2.4 The Systematic School Studies



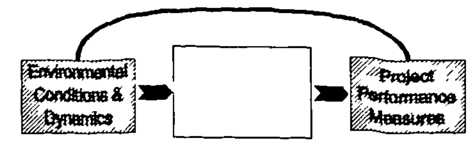
Source: the current study

(6) Project Management Techniques and Computerised Information Systems for Product Innovation (Section 2.5.6).

The above two schools of thought however fall into either Fatalism or Rationalism. In the former case the actual practices of NPD management are less regarded. It was believed that it is not the planting effort but the right seeds that make the trees blossom. In the latter case, there have been too many claims of "only one specific way" for successfully managing NPD. These Systematic School studies largely ignored the fact that any organisation in reality is an open system exposed to external stimuli. Any organisation cannot help but be influenced by its incumbent environment that, in turn, affects the actual organisational behaviour.

With insight drawn from contingency theory of organisation studies, the Design School presented a dynamic view of NPD reality. As a newly emerging stream of thought, the Design School thinking accepted the view of the Systematic School that strategy determines performance. However, their definition of strategy is contingent rather than unitary. NPD management should be tailored for, and adapted to, the corresponding situations, thereby assuring a desirable project outcome. In other words, the Design School "proposes a simple model that views the process as one of design to achieve an essential fit between external threat and opportunity and internal distinctive competence" (Mintzberg, 1990: 171). The application of contingency theory in innovation studies is in its infancy. However, it seems very promising in revealing the real-world practices of NPD management.

§2.4 The Determinants School Studies



Studies from the Determinants School mainly sought to identify factors determining NPD performance. This stream of thought can be traced back to as early as the 1950s. However, it was in the 1970s that the methodical researches of NPD determinants started to appear. In the early determinants studies, the identification of NPD "determinants" was often based on the comparison of activities between technologically innovative and less innovative firms. For example, Carter and Williams (1956) identified 24 factors that highly correlated with technologically progressive firms. These factors include the proficiency of human resource management, marketing information acquisition, R&D cost management, communication and coordination, and the technology synergy of the firm. For these early researchers "determinants" were regarded as general guidelines of NPD management -- they were more interested in generating the "rules" that guide NPD management, rather than the "quantitative models" for forecasting new product performance.

Having benefited from the development of quantitative techniques and computerised analytical tools, the later researches into NPD "determinants" began to employ large sample size and mail survey methods in differentiating successful and unsuccessful NPD projects. Although the managerial proficiency ofNPD activities was still recognised as critical to new product success, very often the focus of these studies was centred on identifying predictors of NPD performance. These predictors were usually the descriptions of characteristics or internal/external environmental situations/conditions of the new product project. Determinants School scholars believed that a careful screening process of these pre-development project characteristics and situations/ conditions was essential, to select the "suitable" projects that fit in with the firm and its surrounding environment and thereby ensures commercial success for the new products.

Previous researches have identified a handful of such determinants associated with NPD performance. However, the main theme in more recent Determinants School studies was the construction of forecast models that can be used to predict project performance before throwing money into an uncertain venture. The actual managerial efforts were in effect largely ignored. The basic structure of these models is a linkage between performance determinants and performance measures. Montoya-Weiss and Calantone (1994) in their remarkable literature review highlighted three major domains of research in linking project determinants and performance, i.e., (1) research on factors leading to success, (2) factors leading to failure, and (3) factors that distinguish between success and failure.

However, from a statistical point of view, these domains fell into two basic research approaches. The first approach directly correlates performance measures with performance determinants in an attempt to identify the impact (e.g., correlation or regression coefficients) of each determinant upon performance (Rubinstein et al., 1976; Cooper, 1981, 1984b, 1987, 1992; Cooper and Kleinschmidt, 1987abc; Voss, 1985; Souder, 1987; de Brentani and Cooper, 1992; Calantone et al., 1993). The second approach first distinguishes observations (i.e., the samples) into different performance groups and then compares the differences among these groups in terms of the mean or frequency of each determinant (Rothwell et al., 1974; Gerstenfeld, 1976; Utterback et al., 1976; Cooper, 1983b, 1985; Cooper and Kleinschmidt, 1990, 1993; Cooper et al., 1994; Maidique and Zirger, 1984; Baker et al., 1986; Link, 1987; Lilien and Yoon, 1990; Zirger and Maidique, 1990; Song and Parry, 1994). Some researchers also combined both approaches so as to provide a more complete picture of their forecast models (Cooper, 1979, 1982; Yoon and Lilien, 1985; Parry and Song, 1994).

Table 2.2 presents a summary of 14 key determinants of new product performance identified by the literature review (A similar classification of determinants can also be found in Montoya-Weiss and Calantone (1994)). The following is a simple categorisation of these determinants. The frequencies and directions of influence of these determinants are also shown in parenthesis. Based on Table 2.2, these determinants therefore can be categorised thus:

A. Product Issues:

- Superior product (positive: 16)

B. Market Issues:

- Attractive marketplace (positive: 16)

C. Synergy and familiarity Issues:

- Production synergy (positive: 11)

- Technology synergy (positive: 19)
- Marketing synergy (positive: 20)

D. Novelty Issues:

- Novelty in process (negative: 2)
- Novelty in technology (positive: 9; negative: 2)
- Novelty in Marketplace (positive: 4; negative: 3)

E. Managerial Issues:

- Managerial support (positive: 6)
- Proficiency in development process (positive: 13)
- Proficiency in launching efforts (positive: 16)

F. Information Issues:

- Know customer needs (positive: 13)
- Clarity of project (positive: 9)
- Sufficient information/communication (positive: 10)

It is clear that the successful recipes in Determinants School's formulas were invariably as follows:

(1) try to avoid high-risk radical projects;
(2) focus only on the attractive market segments;
(3) try to design a superior product that meets customer needs;
(4) stress synergy in production, technology, and marketing;
(5) make commitment to, and be proficient in, managing the development process and launch efforts; and
(6) develop good functional communication and integration.

Although the Determinants School studies have provided very strong statistical evidence in suggesting the above determinants that were eventually the key to new product success, these studies also suffered from several drawbacks. Firstly, it is very unlikely that firms succeed by confining/restricting their NPD efforts to developing and commercialising only familiar products for current markets. Corporate growth theory has long highlighted the role of diversification (i.e., the pursuing of new product and new market development) in sustaining firms' long-term survival (Ansoff, 1957; Johnson and Jones, 1957). Secondly, the essence of entrepreneurship is an eagerness to explore the unknown world. Taking risks may be sometimes strategically important for firms to continue technological advancement (Foster, 1986). Finally, these determinants studies implied that the proficiency of R&D management, communication/integration, and commercialisation are crucial to new product success. However, they did not provide any in-depth analysis of how to achieve such proficiency. To some extent these important activities were regarded as black boxes and were ignored by the Determinants School studies. This created opportunities for other researchers who delved into the core activities of NPD.

Table 2.2 Summary of Determinants School Studies and Key Determinants of NPD Performance

	Sources	Baker et al. (1986)	Calantone et al. (1993)	Cooper (1979)	Cooper (1981)	Cooper (1982)	Cooper (1983b)
	Methodology	ANOVA	Path Analysis	ANOVA, Correlation	Factor, Regression	ANOVA, Correlation	t-Test
	Size and Characteristics of Samples	project level, paired, 110 successes, 101 failures, USA	project level, 142, USA	project level, paired, 102 successes, 93 failures, Canada	project level, paired, 102 successes, 93 failures, Canada	project level, paired, 102 successes, 93 failures, Canada	firm level, 122, Canada
	Performance Measures	Subjectively Nominated	Subjective rating of profitability	Subjective rating of profitability	Perceived project risk (if lower risk)	Subjective rating of profitability	Subjective rating, Success rate, Sales impact
Key Determinants of New Product Performance	Superior Product			+			
	Attractive Marketplace			+			+
	Managerial Support	+					
	Production Synergy	+		+	+		+
	Technology Synergy		+	+	+		+
	Marketing Synergy	+	+	+	+	+	+
	Novelty of Process						-
	Novelty of Technology			+	-		+
	Novelty of Marketplace			+	-		+
	Know Customer Needs	+	+	+			+
	Clarity of Project	+		+	+		
	Sufficient Information/ Communication	+		+			
	Proficiency in Development Process		+	+	+		
	Proficiency in Launch Efforts		+	+		+	
	Other issues	+	+				

Table 2.3 (Continued)

	Sources	Cooper (1984b)	Cooper (1985)	Cooper (1987)	Cooper (1992)	Cooper and Kleinschmidt (1987a)	Cooper and Kleinschmidt (1987b)
	Methodology	Factor, Correlation	Factor, Cluster	Multiple Regression	Regression	Correlation	Correlation
	Size and Characteristics of Samples	firm level, 122, Canada	firm level, 122, Canada	firm level, 120, Canada	project level, n=? (NewProd database)	project level, 252, Canada	project level, paired, 123 successes, 80 failures, Canada
	Performance Measures	Subjective rating, Success rate, Sales impact	Subjective rating, Success rate, Sales impact	Subjective rating	Subjective rating of profitability	Financial Performance, Market impact, Opportunity window	Financial performance, Market impact, Opportunity window
Key Determinants of New Product Performance	Superior Product		+	+	+	+	+
	Attractive Marketplace	+	+	+	+	+	+
	Managerial Support						
	Production Synergy	+		+			+
	Technology Synergy	+		+	+	+	+
	Marketing Synergy	+		+	+	+	+
	Novelty of Process						
	Novelty of Technology	+	+	+			
	Novelty of Marketplace		-				
	Know Customer Needs	+				+	
	Clarity of Project				+	+	+
	Sufficient Information/ Communication					+	
	Proficiency in Development Process					+	
	Proficiency in Launch Efforts					+	
	Other Issues						

Table 2.3 (Continued)

	Sources	Cooper and Kleinschmidt (1987c)	Cooper and Kleinschmidt (1990)	Cooper and Kleinschmidt (1993)	Cooper et al. (1994)	de Brentani and Cooper (1992)	Globe et al. (1973)
	Methodology	Correlation	Duncan Analysis	ANOVA, t-Test	t-Test, Duncan Analysis	Correlation	Frequency
	Size and Characteristics of Samples	project level, paired, 123 successes, 80 failures, Canada	project level, paired, 123 successes, 80 failures, 47 killed, Canada	project level, 103, USA, Canada, UK, Germany	project level, 173, Canada	project level, paired, 56 successes, 50 failures, Canada	proejct level, Case study, 10 successes, USA
	Performance Measures	Subjective rating of profitability	Subjectively Nominated	Subjective rating and objective financial measures	Factor: financial performance, relationship enhancement, and market development	Subjectively Nominated	Subjectively Nominated
Key Determinants of New Product Performance	Superior Product	+	+		+	+	
	Attractive Marketplace	+	+				
	Managerial Support						
	Production Synergy						
	Technology Synergy	+				+	+
	Marketing Synergy	+			+	+	
	Novelty of Process						
	Novelty of Technology				+		
	Novelty of Marketplace						
	Know Customer Needs						+
	Clarity of Project	+		+			
	Sufficient Information/ Communication				+		
	Proficiency in Development Process	+		+	+	+	
	Proficiency in Launch Efforts	+		+	+	+	
	Other Issues			+	+		+

Table 2.3 (Continued)

	Sources	Lilien and Yoon (1990)	Link (1987)	Maidique and Zirger (1984)	Parry and Song (1994)	Roberts and Burke (1974)	Rothwell et al. (1974)	Rubinstein et al. (1976)
	Methodology	Markovian Decision Model and Discriminant	Factor Analysis	Binomial Significance Tests and Cluster Analysis	t-Test, Correlation	Case study	Univariate, Factor, Cluster	Correlation
	Size and Characteristics of Samples	project level, 91, France	firm level, 135, Australia	project level, 59, USA	project level, paired, 147 successes, 129 failures, China	6 successes, USA	project level, paired, 43 successes, 43 failures, UK	project level, 103 successes, USA
	Performance Measures	Opportunity Window	Subjective rating	Financial Breakeven	Subjective rating of profitability	Subjectively Nominated	Profitability	Subjective rating
Key Determinants of New Product Performance	Superior Product		+	+	+			
	Attractive Marketplace	+	+		+			
	Managerial Support					+		+
	Production Synergy		+		+	+		
	Technology Synergy		+	+	+			
	Marketing Synergy	+			+			
	Novelty of Process				-			
	Novelty of Technology		+	+	+			
	Novelty of Marketplace		+					
	Know Customer Needs		+	+	+	+	+	
	Clarity of Project							
	Sufficient Information/ Communication			+	+		+	+
	Proficiency in Development Process			+	+		+	
	Proficiency in Launch Efforts	+	+	+	+		+	
	Other Issues			+		+		+

Table 2.3 (Continued)

	Sources	Song and Parry (1994)	Souder (1987)	Souder and Chakrabarti (1979)	Utterback et al. (1976)	Voss (1985)	Yoon and Lilien (1985)	Zirger and Maidique (1990)
Methodology		Factor, Discriminant	Correlation	Frequency	Chi-square test	Spearman rank order Correlation	ANOVA, Regression	Factor, Discriminants
Size and Characteristics of Samples		project level, 235, USA	project level, 235, USA	project level, paired, USA, 49 successes, 53 failures, 14 killed	project level, paired, Germany, UK, France, Japan, Netherland 66 successes, 51 failures, 47 on going	project level, 16 successes, UK	project level, 112 successes, France	project level, paired, USA, 77 successes, 71 failures
Performance Measures		Subjective rating	Subjective rating	?	Subjectively Nominated	Subjective rating	Initial sales, Market share	Subjective rating of profitability
Key Determinants of New Product Performance	Superior Product	+			+			+
	Attractive Marketplace	+					+	+
	Managerial Support			+		+		+
	Production Synergy							+
	Technology Synergy	+	+	+				+
	Marketing Synergy	+		+	+			+
	Novelty of Process							
	Novelty of Technology			-				
	Novelty of Marketplace						+/-	
	Know Customer Needs		+	+				
	Clarity of Project		+					
	Sufficient Information/ Communication			+		+		
	Proficiency in Development Process		+			+		
	Proficiency in Launch Efforts					+	+	+
	Other Issues		+		+	+		+

Note: + positive relationship; - negative relationship; ? not reported in the original article.
Source: the current study

§2.5 The Systematic School Studies

Unlike the Determinants School of thought that treated the core activities in R&D management as a black box, the Systematic School studies eventually investigated the actual practices of NPD. They argue that the project/product's characteristics and its incumbent environment are not the most significant factors that decide new product performance. On the contrary, they stress that it is managerial practice that matters. However, by differentiating their research approaches and theoretical bases, this school of thought can further be subdivided into several streams of studies, namely:

- the Generic Recipe Studies,
- the Communication Pattern Studies,
- the Interface Studies,
- the Organisational Learning Studies,
- the Japanese Practice Studies, and
- other studies concerning project management techniques and NPD information systems.

2.5.1 The Generic Recipe Studies

The Generic Recipe studies treated NPD as part of the conventional general management that cannot be separated from overall corporate managerial operations. They argued that NPD, like other functional activities, should be integrated into corporate management systems, having the same weighting as other functional departments. Therefore the successful management of NPD requires commitment of vision, mission, and strategy at top management level as well as the consolidation of shared values, management style, and structural arrangement for the company as a whole. The core in NPD management, as in general management, is people and associated human activity, not the task-related components such as operational procedures or managerial information. As Johne and Snelson (1988: 114) pointed out, the main analytical perspectives in NPD are:

(1) a consideration of the market and operating environment of the firm;

(2) a consideration of the actions or attributes of the firm as a whole;

(3) a consideration of the group of people within a firm involved in development work; and

(4) a consideration of particular individuals who are or ought to be involved.

In fulfilling the view of NPD management as a miniature of general managerial efforts, researchers have highlighted a variety of managerial factors that are empirically or theoretically regarded as influencing NPD performance (e.g., Quinn, 1985; Peters, 1990, 1991; Rothwell, 1992). Other scholars also concentrated their efforts on one or two of these key factors so as to provide a more in-depth view of successful NPD management. (e.g., Jermakowicz, 1978; Sommers, 1982; Shrivastava and Souder, 1987). While these studies have contributed much to reveal the secret of industrial NPD excellence, there was considerable variation across studies in terms of their suggested "generic recipes". Analytical schemes are required to form these "generic recipes" into more manageable checklists. For this purpose, some scholars suggested using the McKinsey 7 Ss model (i.e., structure, strategy, systems, shared values, skills, style, and staff) for organising these factors (e.g., Johne and Snelson, 1988; Dwyer, 1990; Grady and Fincham, 1990). Although one major criticism about the 7 Ss model was raised arguing that such an over-simplified model cannot capture the full nature of organisational complexity, this model is still very useful in providing a systematic and meaningful general view of these managerial practices. By following these studies, the current literature review uses the 7 Ss framework to organize the Generic Recipe studies. A summary of these managerial factors for effective NPD is presented in Table 2.3.

Structure

While considering the structure issues in NPD management, one should first acknowledge that there are at least two distinct levels of R&D organisational arrangement, i.e., the corporate level and the project level. At the corporate level the focus of R&D organisational deployment deals with the relationship between R&D and other functional departments. At the project level the management of R&D structure is concerned with how a specific project organisation is constructed.

At the corporate level of NPD structure deployment, many researchers favour the small, flat, and organic structure (e.g., the project matrix structure) which was believed to accelerate organisations' innovativeness (Quinn, 1985; Shrivastava and Souder, 1987; Peters, 1990; Rothwell, 1992; Saleh and Wang, 1993). On the contrary, other scholars also argued that the large, formal, and centralised research laboratory (i.e., the pure line structure) is more efficient in sharing scarce resources and improving R&D productivity (Grady and Fincham, 1990).

It is clear that there are trade-offs between these two extreme structures. As Jermakowicz (1978) stated, the rigid or formal structure provides the highest productivity of outcomes while the flexible or informal one promotes innovativeness. To achieve both productivity and innovativeness, he conceptualised a new form of NPD structure labelled "Creative-matrix Project-production Structure" that combines both the rigid and the flexible organisational structures simultaneously. This new form of structure in effect was a task force (or venture team as he suggested) at the project-level, and was supported by a matrix organisation at the corporate-level. At the project-level the task force structure (i.e., pure-line organisation) would provide the necessary productivity for development work. At the corporate-level, the matrix structure would maintain the flexibility of company-wide operations. However, the effectiveness of this model was not empirically examined.

In addition to the above differences concerning the structures that facilitate either technological innovativeness or productivity, there was also disagreement about the "control mechanisms" of corporate NPD organisational settings. Some scholars highlighted the necessity of a "marketing dominated" structure, claiming that all NPD activities should be triggered and directed by marketing people (e.g., Johne, 1992). On the other hand, Workman, Jr. (1993) asserted that innovation is something to do with the unknown future that cannot be predicted by any formal marketing research technique. Therefore, the marketing people should keep a low profile in NPD decisions. An "R&D dominated" structure would be better in facilitating new ideas and accelerating radical technological developments.

Instead of the above assertions that are based on hierarchical control concepts, Grady and Fincham (1990) and Whittington (1991) suggested a compromise arrangement for managing NPD structure. By exploiting the concept of "client-server" or "customer-contractor" principle, they proposed a centralised research laboratory that is granted formal autonomy from operational management but is dependent upon its ability to win the contracts from divisions (or outside the company) for survival. On the other hand, the divisions decide independently whether to "buy" R&D from the laboratory or from other outside contractors. Therefore the control process is market-driven rather than directed by a hierarchy.

Besides the above corporate-level structure studies, most researchers at the project-level preferred multi-function (Ansoff, 1987; Bertodo, 1988; Peters, 1990) and multi-layer (Kumpe and Bolwijn, 1994) project structures. They proposed that both the functional and the hierarchical barriers should be broken so as to facilitate multi-discipline communication and integration. Empirically, Larson and Gobeli (1988) and Gray et al. (1990) all suggested that both project matrix and project team structures performed well in the NPD situation. Peters (1990) further highlighted the benefits of geographically "co-located joint-function teams". However, Quinn (1985) observed that rather than the balanced multi-functional venture group, the entrepreneurial task force is the ideal model for radical NPD. He argued that the "balanced" policy of team composition is far more rigid and less effective in fertilizing innovation. What eventually accelerates NPD is the structural design that allies a group of people who embrace a dream to consolidate and develop "their" entrepreneurial ideas. The contingent view of NPD structure upon project types will be further discussed in Section 2.6, the Design School studies.

Shared Values

The concept of shared values in NPD drew greater consensus among researchers. Most writers agreed that in an innovative and successful company top management and employees should share the same values:

- customer-orientation (Parkinson, 1981; Quinn, 1985; Dwyer, 1990; Millett, 1990; Grady and Fincham, 1990; Gemünden et al., 1992; Rothwell, 1992; Kumpe and Bolwijn, 1994),

- risk-taking (Quinn, 1985; Khan and Manopichetwattana, 1989; Rothwell, 1992; Saleh and Wang, 1993),
- pressures of time (Quinn, 1985; Peters, 1990; Kumpe and Bolwijn, 1994), and
- entrepreneurial spirit (Quinn, 1985; Ansoff, 1987; Johne and Snelson, 1988; Dwyer, 1990; Capon et al., 1992; Rothwell, 1992; Saleh and Wang, 1993).

Team spirit and a company-wide commitment to NPD are also called for, increasing the strength of NPD capability (van de Ven, 1986; Johne and Snelson, 1988; van der Meer and Calori, 1989; Dwyer, 1990; Peters, 1990; Rothwell, 1992; Saleh and Wang, 1993). The resultant organisational climate is therefore one that spreads warmth, openness, and trust around the organisation (Shrivastava and Souder, 1987; Johne and Snelson, 1988; Peters, 1991).

Besides the above general impact of overall corporate atmosphere, scholars also highlighted the importance of promoting a flexible attitude that welcomes multiple innovation approaches (Quinn, 1985), and one which accepts failures and encourages staff to learn from unsuccessful experiences (Mansfield, 1981; Peters, 1991). Eagerness for pursuing new scientific knowledge and technology should be encouraged (Capon et al., 1992). Quinn (1985) also stressed the necessity of a long-term enthusiasm for all these entrepreneurial activities.

Style

Top management support and involvement in R&D activities have been widely shown to impact new product outcome (Quinn, 1985; Johne and Snelson, 1988; Dwyer, 1990; Rochford, 1991: 291). An open-door managerial style is required, thus removing the vertical barriers of communication (Kumpe and Bolwijn, 1994). However, the high involvement of top management in NPD also has its pros and cons: on one hand it may provide the necessary advocacy for the project which often requires a great deal of company resources; on the other hand, it may also bring too much unnecessary intervention to project development. For example, while some scholars stressed the role of top management as technology experts and fanatics in NPD activities (Quinn, 1985), others indicated the need for high authority and autonomy of the NPD function (Johne and Snelson, 1988; Peters, 1990). Might and Fischer (1985) and Clark and Fujimoto

(1991) have even been promoting the idea of the "heavy-weight" project manager. Not surprisingly, the balance between autonomy and control has been one of the key issues in project administration (Garnsey and Wright, 1990).

Scholars also suggested that the method and attitude of project managers in team management are essential to project performance. Risk-taking should be encouraged (Quinn, 1985; Johne and Snelson, 1988; Khan and Manopichetwattana, 1989; Rothwell, 1992; Saleh and Wang, 1993). Goal clarity is critical (van der Meer and Calori, 1989), and group decision-making in project planning is very useful (Kernaghan and Cooke, 1986). Project managers also need to develop a positive attitude to conflicts among members, so as to appreciate the aspiration of individuals (Johne, 1992).

Staff

People are the core interest in NPD management according to the Generic Recipe studies. The ability to attract and retain talented managers and researchers has long been the major challenge in R&D management (Johne and Snelson, 1988; Capon et al., 1992; Rothwell, 1992). Success in this important managerial task is largely dependent upon the policies of recruitment, career paths, and reward systems designed for R&D members. Although qualifications and research ability are normally the major criteria for most firms in recruiting R&D members, Peters (1991) in addition has stressed entrepreneurship as another important consideration for identifying the right candidates. He advocated the concept that the "renegades" are in essence the real entrepreneurs who always stand head and shoulders above their peers and therefore should be hired, appreciated, and protected.

However, it is much easier to hire people than to retain them. The major difficulties in NPD staffing have been the narrow career opportunity for the technical engineers and a lack of indicators for measuring their performance. To provide a wider range of career paths in R&D human resource development, most scholars suggested the parallel career paths (i.e., technical path and managerial path) for technical staffs (e.g., Kumpe and Bolwijn, 1994). Moreover, Peters (1991) has provided a more innovative idea, to crack this problem by establishing a horizontal project career track from the beginning. As he observed:

> *The pursuit of a thicker carpet, a private secretary, a private line to the president's office is not the pursuit of success in today's frenetic world. "Horizontal promotion," as British researcher Charles Handy calls it, now must become the norm ... When asked why they were spending 18 or 20 hours a day, six or seven days a week, several members responded in almost the same fashion. "To get a chance to play the game again." That is, to try and win so as to be allowed to go on an even more exotic project* (p.11).

With regard to the reward systems for R&D function, scholars stated the role of intangible factors that facilitate NPD performance. Quinn (1985) and Taylor (1990: 102) both suggested that the psychological individual recognition and appreciation, rather than tangible rewards, are far more effective for technical personnel motivation. Taylor (1990: 101) in addition pointed out the proper occasions for rewarding, i.e., not just to reward success, but in essence to reward the intelligent effort (even when it was a failure). Finally, the "gate-keepers" should especially be appreciated and promoted so as to encourage information acquisition and transmission during NPD (Rothwell, 1992; Kumpe and Bolwijn, 1994).

Systems

The nature of a system in essence is a reflection of its incumbent structure. As mentioned above, there are differences of opinion among the suggestions for NPD structural design, and so disagreements of approaches to managing NPD systems. Empirical evidence has shown that the employment of formal managerial systems and development procedures were highly related to NPD success (Booz, Allen & Hamilton, 1982; Boag and Rinholm, 1989; Cooper, 1990; Dwyer, 1990; Cooper and Kleinschmidt, 1991). However, other researchers stressed the importance of informal communication channels (van de Ven, 1986; Johne and Snelson, 1988; Grady and Fincham, 1990) and flexible systems (Garnsey and Wright, 1990) that allow key people to communicate and share problems/solutions. Corporate flexibility and responsiveness to change are called for, so as to cope better with the turbulent environment (Johne and Snelson, 1988; Rothwell, 1992).

Besides the above disagreement, most scholars generally accepted that an effective NPD system should be the one that encourages communication and integration between different functions (Ansoff and Stewart, 1967; Hopkins, 1981; Mansfield, 1981; Johne and Snelson, 1988; van der Meer and Calori, 1989; Dwyer, 1990; Rothwell, 1992; Saleh and Wang, 1993), between different levels of the hierarchy (Millett, 1990; van der Meer and Calori, 1989), and between the organisation and the world outside (Rothwell, 1992). To facilitate such communication and integration, Taylor (1990: 102) suggested a corporate "not invented here (NIH)" champion of idea generation and sharing to promote multi-functional knowledge circulation. Abernathy (1971) and Quinn (1985) also suggested a competing parallel approach to the NPD process. They argued that a parallel project champion in the early NPD stages could be very useful in avoiding the problem of group thinking while encouraging idea generation, diffusion, and consolidation, and to enhance corporate commitment to the project. Finally, the popularisation of client-server networking for low cost personal computers benefits company-wide NPD communication (Johne, 1992).

Skills

Proficiency in managing a variety of activities during each stage of the development process is the basis of successful NPD (Johne and Snelson, 1988; Rothwell, 1992). To achieve such a proficiency, firms require specific skills to disseminate consumer needs and market trends from marketing-related activities (Hopkins, 1981; Johne and Snelson, 1988; Ayal and Raban, 1990) and know-how from research efforts to applied development and engineering (Kumpe and Bolwijn, 1994). Quinn (1985) called these skills the ability to deal with chaos and uncertainty. According to the literature, these skills also include the ability to include new product planning in corporate planning system (Johne and Snelson, 1988), the ability to acquire sufficient capital for the venture (Quinn, 1985; van der Meer and Calori, 1989), the proficiency of team management (Grady and Fincham, 1990), the ability to deal with technical problems (Hopkins, 1981), and the vision of a proper timing for the product launch (Hopkins, 1981). Some scholars in addition stressed the role of learning as another basic skill in NPD. Quinn (1985) highlighted the ability of interactive learning of R&D members as crucial for NPD. Van de Ven (1986) further recognized the common syndrome of professional people that tend to addict themselves to a specific technical area. He asserted that the skill for R&D people to identify and appreciate new

Table 2.3 Summary of Generic Recipe Studies

Success Ingredients	Theoretical Assertions	Case Observations or Empirical Conclusions
Structure	¤ Multi-layer project team (Kumpe and Bolwijn, 1994) ¤ A Marketing-dominated structure (Johne, 1992) ¤ "Creative-matrix project-production structure" (a combination of matrix and pure line project structure) was suggested as the best solution of R&D organisation (Jermakowicz, 1978) ¤ Multi-function project team (Ansoff, 1987; Bertodo, 1988) ¤ In favour of organic structures (Shrivastava and Souder, 1987; Rothwell, 1992) ¤ In favour of small and flat organisational structures (Peters, 1990) ¤ In favour of centralised research laboratory (Grady and Fincham, 1990) ¤ A "Market Control" structure that R&D has formal autonomy from operational management and the control is exercised indirectly through market mechanisms, rather than directly by hierarchy (Grady and Fincham, 1990) ¤ Co-located joint-function team (Peters, 1990) ¤ Division member as project manager (Grady and Fincham, 1990) ¤ Assign researchers to project teams from total pool -- no "walls" within research (Grady and Fincham, 1990)	¤ In favour of small and flat organisational structures (Quinn, 1985) ¤ In favour of organic structures (Saleh and Wang, 1993) ¤ In favour of the entrepreneurial task force rather than the balanced multi-functional venture group (Quinn, 1985) ¤ A "Market Control" structure that R&D has formal autonomy from operational management and the control is exercised indirectly through market mechanisms, rather than directly by hierarchy (Whittington, 1991). ¤ A R&D-dominated but Customer-oriented structure (Workman, Jr., 1993) ¤ Project matrix and project team structures were the most effective structures for NPD (Larson and Gobeli, 1988; Gray et al., 1990)
Shared Values	¤ Customer-oriented (Grady and Fincham, 1990; Rothwell, 1992; Kumpe and Bolwijn, 1994) ¤ Risk taking (Rothwell, 1992) ¤ Time-driven (Peters, 1990; Kumpe and Bolwijn, 1994) ¤ Entrepreneurial orientation (Ansoff, 1987; Johne and Snelson, 1988; Rothwell, 1992) ¤ Develop and share a warmth, openness, and trust organisation climates (Shrivastava and Souder, 1987; Johne and Snelson, 1988; Peters, 1991) ¤ Commitment and team spirit (van de Ven, 1986; Johne and Snelson, 1988; Peters, 1990; Rothwell, 1992) ¤ Innovation as a corporate wide task (Rothwell, 1992) ¤ Commitment to postpurchase service (Rothwell, 1992) ¤ Incremental improvement as a continuous must (Peters, 1991) ¤ Cheer and Learn from failures (Mansfield, 1981; Peters, 1991)	¤ Customer-oriented (Parkinson, 1981; Quinn, 1985; Dwyer, 1990; Millett, 1990; Gemünden et al., 1992) ¤ Risk taking (Quinn, 1985; Khan and Manopichetwattana, 1989; Saleh and Wang, 1993) ¤ Time-driven (Quinn, 1985) ¤ Entrepreneurial orientation (Quinn, 1985; Dwyer, 1990; Capon et al., 1992; Saleh and Wang, 1993) ¤ A long-term entrepreneurial view (Quinn, 1985) ¤ Commitment and team spirit (van der Meer and Calori, 1989; Dwyer, 1990; Saleh and Wang, 1993) ¤ A flexible attitude to multiple innovation approaches (Quinn, 1985) ¤ An enthusiasm for new scientific knowledge/inventions (Capon et al., 1992)

Table 2.3 (Continued)

Success Ingredients	Theoretical Assertions	Case Observations or Empirical Conclusions
Style	¤ Top management involvement in the opportunity identification process (Rochford, 1991: 291) ¤ Hierarchical by-passes and open-door management style (Kumpe and Bolwijn, 1994) ¤ Not to suppress but to confront conflicts and to align aspirations of individuals (Johne, 1992) ¤ High authority and autonomy of divisions (Johne and Snelson, 1988; Peters, 1990) ¤ Top management support for R&D (Johne and Snelson, 1988) ¤ Risk taking by top management (Johne and Snelson, 1988; Rothwell, 1992)	¤ Heavy-weight project manager (Might and Fischer, 1985; Clark and Fujimoto, 1991) ¤ Group decision making in project planning (Kernaghan and Cooke, 1986) ¤ A balance of autonomy and control in research administration (Garnsey and Wright, 1990) ¤ CEOs as technology experts and fanatics (Quinn, 1985) ¤ Goal clarity in management (van der Meer and Calori, 1989) ¤ Risk taking by top management (Quinn, 1985; Khan and Manopichetwattana, 1989; Saleh and Wang, 1993) ¤ Top management support for R&D (Dwyer, 1990)
Staff	¤ Parallel career paths for technical staffs (Kumpe and Bolwijn, 1994) ¤ Promote "gate-keepers" (Rothwell, 1992; Kumpe and Bolwijn, 1994) ¤ Ability to attract and retain talented managers and researchers (Johne and Snelson, 1988; Rothwell, 1992) ¤ Hire and protect renegades (because they are entrepreneurial) (Peters, 1991) ¤ Establish a horizontal project career track from the beginning (Peters, 1991)	¤ Not only just reward success, but in essence reward intelligent effort (Taylor, 1990: 101). ¤ Individual recognition rather than tangible rewards is a better means of personnel motivation (Quinn, 1985; Taylor, 1990: 102). ¤ Recruit talented scientific personnel (Capon et al., 1992)
Systems	¤ High downstream (multi-functional) coupling (Ansoff and Stewart, 1967; Johne and Snelson, 1988; Rothwell, 1992) ¤ A close link between R&D and marketing (Mansfield, 1981; Johne and Snelson, 1988) ¤ The utilisation of computer networking (Johne, 1992) ¤ Delegated self-management control system (Bertodo, 1988) ¤ Use more informal communication channels (van de Ven, 1986; Johne and Snelson, 1988; Grady and Fincham, 1990) ¤ Good internal and external communications (Rothwell, 1992) ¤ Formal managerial systems and development procedures (Johne and Snelson, 1988; Grady and Fincham, 1990; Rothwell, 1992) ¤ Corporate flexibility and responsiveness to change (Johne and Snelson, 1988; Rothwell, 1992) ¤ Installation of project tracking system (Grady and Fincham, 1990)	¤ Regular top-down and bottom-up communication (Millett, 1990; van der Meer and Calori, 1989) ¤ Encourage "Not Invented Here" idea generating, diffusion, and sharing (Taylor, 1990: 102). ¤ A flexible system that allows key people to share problems/solutions across the organisation (Garnsey and Wright, 1990) ¤ Competing parallel development approach in early development stages (Quinn, 1985) ¤ Formal managerial systems and development procedures (Booz, Allen and Hamilton, 1982; Boag and Rinholm, 1989; Dwyer, 1990; Cooper, 1990; Cooper and kleinschmidt, 1991) ¤ A close linkage among different functions (Hopkins, 1981; van der Meer and Calori, 1989; Dwyer, 1990; Saleh and Wang, 1993)

Table 2.3 (Continued)

Success Ingredients	Theoretical Assertions	Case Observations or Empirical Conclusions
Skills	¤ Effective dissemination of know-how from Research to Applied Development and Engineering (Kumpe and Bolwijn, 1994) ¤ The ability to trigger members' action thresholds to pay attention to new ideas, new needs, and opportunities (van de Ven, 1986) ¤ Efficiency in development work and high quality production (Johne and Snelson, 1988; Rothwell, 1992) ¤ The ability to incorporate new product planning to corporate planning system (Johne and Snelson, 1988). ¤ Proficiency in marketing related activities (e.g., marketing planning, marketing communication, marketing research and economic assesssment (Johne and Snelson, 1988) ¤ Proficiency in team management (Grady and Fincham, 1990)	¤ Proficient in marketing related activities (e.g., marketing planning, marketing communication, marketing research and economic assesssment) (Hopkins, 1981; Ayal and Raban, 1990) ¤ The ability to deal with chaos and uncertainty in innovation (Quinn, 1985) ¤ The ability to acquire sufficient capital for the ventures (Quinn, 1985; van der Meer and Calori, 1989) ¤ Encourage interactive learning (Quinn, 1985) ¤ Ability to deal with technical problems (Hopkins, 1981) ¤ The vision of a proper timing for product launch (Hopkins, 1981)
Strategy	¤ Balanced Strategy: a balance of technology newness and market newness (Mansfield, 1981; Johne and Snelson, 1988; Rothwell, 1992) ¤ Keep NPD strategy consistent with corporate strategy (Shrivastava and Souder, 1987) ¤ Regard innovation as a key component in long-term corporate strategy (Rothwell, 1992) ¤ License and sell off old technology to force dependence on the new (Peters, 1990) ¤ Subcontracting (Peters, 1990) Global alliances and joint ventures (Peters, 1990) ¤ Conduct joint development projects with lead customers and vendors (Peters, 1990)	¤ High degrees of strategic focus (Meyer and Roberts, 1986; van der Meer and Calori, 1989) ¤ Balanced Strategy: a balance of technology newness and market newness (Cooper, 1984a, 1985; Meyer and Roberts, 1986; Brockhoff and Pearson, 1992) ¤ Offensive/proactive strategy (Khan and Manopichetwattana, 1989; Saleh and Wang, 1993) ¤ Keep early costs down (Quinn, 1985) ¤ Keep close linkages with customer, universities, and other companies (Gemünden et al., 1992)

ideas, new needs, and opportunities from other disciplines is highly important for effective NPD management.

Strategy

Most researchers agreed that the development of NPD strategy should be the one that promotes a balanced view of both technology newness and market newness (Mansfield, 1981; Cooper, 1984a, 1985; Meyer and Roberts, 1986; Johne and Snelson, 1988; Brockhoff and

Pearson, 1992; Rothwell, 1992). Scholars also stressed the necessity of NPD strategy as the key component in long-term corporate strategy (Rothwell, 1992) and the necessity of its consistency with such corporate strategy (Shrivastava and Souder, 1987). Meyer and Roberts (1986) and van der Meer and Calori (1989) claimed that a high degree of strategic focus is essential. Some empirical evidence in addition showed that the firm's pursuit of offensive/proactive NPD strategy was highly associated with new product success (Khan and Manopichetwattana, 1989; Saleh and Wang, 1993).

Strategic linkage of R&D function with the outside world was also frequently cited as an important factor for successful NPD. Gemünden et al. (1992) stated the need for keeping close links with customers, universities, and other companies. Peters (1990) suggested a joint development scheme of R&D function with main customers and vendors. Moreover, he also proposed that global alliances and joint ventures were highly necessary to acquire new concepts and to "create market power through size."

To conclude, the Generic Recipe scholars have provided a complete set of tools and guidelines for managing NPD activities. However, their inward focus of research solely on internal managerial activities may make it difficult to describe the dynamic nature of NPD. Furthermore, the consideration of NPD reality as conventional general management that treats NPD activities and relative human behaviour as the only key components in NPD may be insufficient. For many other scholars NPD is not only the management of a series of tasks or activities but also a process of information processing and knowledge creation and accumulation. It may be equally important to learn more about the nature of these information/knowledge works so as to understand successful NPD.

2.5.2 The Communication Pattern Studies

Having inherited the view of NPD as a "technology-push" process from the early innovation studies, the Communication Pattern researchers saw the reality of NPD management as the efforts of managing the community of scientists/engineers. They asserted that the major events in NPD are the acquisition and transmission of science/technology information between

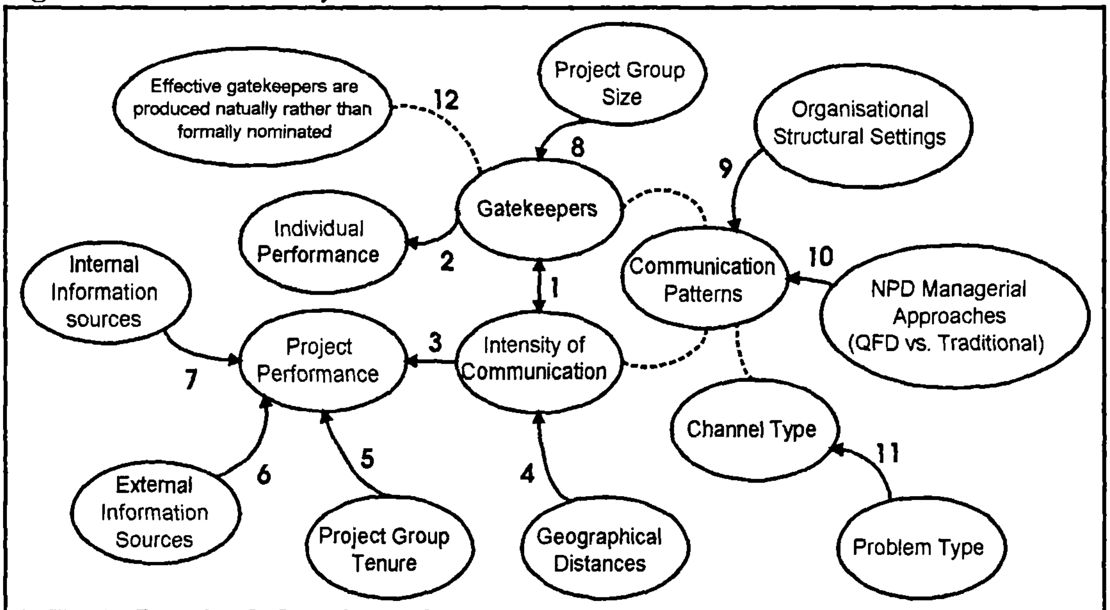
R&D members as well as between the R&D function and the outside world. By focusing on observing such communities, the key considerations of these studies were how the communication patterns among individuals influence project performance, and what are the underlying factors that determine communication patterns.

T.J. Allen and his colleagues at MIT were among the first to standardize the methodology for researching into scientific communication patterns (Allen, 1966abc; Allen and Cohen, 1969; Allen and Fustfeld, 1975; Allen et al., 1980; Katz and Allen, 1982; Nochur and Allen, 1992). They employed a methodology that was later labelled as "Network Analysis"[4] to identify the communication roles of R&D members and measure the intensity of technological communication within large science-based institutes. They observed that the typical communication pattern within research laboratories is similar to a complex network where individuals must directly or indirectly talk to each other. A small number of scientists/engineers who are especially active in transferring and disseminating information from the outside world and within the laboratory were identified as "gatekeepers" and were regarded as the key persons to facilitate innovation. The emphases of Communication Pattern studies therefore were centred on the relationship of the gatekeepers and the surrounding communication networks. The subsequent researchers more or less followed Allen's methodology to reveal the influences and patterns of R&D communication (Frost and Whitley, 1971; Shotwell, 1971; Hough, 1972; Walsh and Baker, 1972; Hall and Ritchie, 1975; Taylor and Utterback, 1975; Pruthi and Nagpaul, 1978; Nagpaul and Pruthi, 1979; Tomlin, 1981; Myers, 1983; Sullo et al., 1985; Hauptman, 1986; Wigand and Frankwich, 1989; Griffin and Hauser, 1992). Figure 2.5 presents a summary of the Communication Pattern studies. The following are the main conclusions of these studies.

(1) Definition of Gatekeepers

Most scholars have defined and identified the gatekeepers as the people who are central to external and internal information transmission. They are more likely to transmit external information to the organisation and have higher intensity of communication than their peers (Allen, 1970; Frost and Whitley, 1971; Taylor and Utterback, 1975; Epton, 1981; Myers, 1983; Sullo et al., 1985; Hauptman, 1986). Opposing this view, Shotwell (1971) and Walsh and Baker

Figure 2.5 Summary of the Communication Pattern Studies



Links	*Empirical Results*	*Sources*	*Information Type*	*Scope of Study*	*Methodology*	*Sample Size*
1	Gatekeepers have higher intensity of communication than others	Allen (1970)	(A summary of several published or unpublished studies)			
		Frost and Whitley (1971)	technical	intra-lab	network analysis	?
		Hall and Ritchie (1975)	not specified	intra-lab	network analysis	?
		Taylor and Utterback (1975)	technical	intra-lab	network analysis	184
		Epton (1981)	(literature review)			
		Myers (1983)	technical	intra-lab	network analysis	52
		Sullo et al. (1985)	not specified	intra-project	network analysis	11
		Hauptman (1986)	technical	intra-lab	network analysis	508
	Gatekeepers were not identified	Shotwell (1971)	not specified	intra-lab	network analysis	43
		Walsh and Baker (1972)	technical and project control	intra-lab	network analysis	35
2	Gatekeepers are high performers	Allen (1970)	(A summary of several published or unpublished studies)			
	Gatekeepers are not always high performers	Frost and Whitley (1971)	technical	intra-lab	network analysis	?
3	Higher communication intensity results in better performance	Allen (1970)	(A summary of several published or unpublished studies)			
		Epton (1981)	(literature review)			
		Hauptman (1986)	technical	intra-lab	network analysis	508
4	Geographical distances reduce communication	Allen (1970)	(A summary of several published or unpublished studies)			
		Hough (1972)	technical	intra-firm	network analysis	?
		Walsh and Baker (1972)	technical and project control	intra-lab	network analysis	35
		Evans et al. (1974)	not specified	intra-lab	network analysis	?
		Allen and Fustfeld (1975)	technical	intra-firm	network analysis	512
		Hall and Ritchie (1975)	not specified	intra-lab	network analysis	?
		Epton (1981)	(literature review)			
		Tomlin (1981)	technical	inter-lab	network analysis	150

Figure 2.5 (Continued)

Links	*Empirical Results*	*Sources*	*Information Type*	*Scope of Study*	*Methodology*	*Sample Size*
5	An inverted U-shaped relationship between team tenure and performance	Katz and Allen (1982)	technical	intra-lab	network analysis	345
6	Access to external information sources increases performance	Allen (1970)	(A summary of several published or unpublished studies)			
		Dewhirst et al. (1978)	not specified	intra-lab	spearman rank order correlation	302
7	Access to internal information sources increases performance	Dewhirst et al. (1978)	not specified	intra-lab	spearman rank order correlation	302
		Allen et al. (1980)	technical	intra-lab	network analysis	345
8	The validity of gatekeeper role gets diluted as the project group size decreases	Pruthi and Nagpaul (1978)	not specified	intra-project	network analysis	45
		Nagpaul and Pruthi (1979)	not specified	intra-project	network analysis	45
9	Organisational structure settings influence communication patterns	Hall and Ritchie (1975)	not specified	intra-lab	network analysis	?
		Taylor and Utterback (1975)	technical	intra-lab	network analysis	184
		Pruthi and Nagpaul (1978)	not specified	intra-project	network analysis	45
10	NPD managerial approaches influence communication patterns	Griffin and Hauser (1992)	not specified	inter-function	network analysis	?
11	Type of problem in NPD influences the selection of communication channels	Holland et al. (1976)	not specified	intra-lab	correlation	384
		Stevenson and Gilly (1991)	not specified	inter-firm	hypothetical scenarios with network analysis	272
	Problem type doesn't influence the selection of communication channels	Nagpaul and Pruthi (1979)	not specified	intra-project	network analysis	45
12	Effective gatekeepers appear naturally rather than formally nominated	Nochur and Allen (1992)	not specified	intra-lab	network analysis	39

? denotes that the sample size was not reported in the original work.

(1972) argued that the gatekeeper role may not be so explicit and so important as suggested by Allen and his colleagues.

(2) Individual Performance and Gatekeepers

Allen (1970) summarized a series of researches conducted at MIT and asserted that the gatekeepers are often the high performers in the laboratory. However, Frost and Whitley (1971)'s finding suggested that the gatekeepers need not necessarily be high performers.

(3) R&D Performance and Communication Intensity

In general, most scholars accepted that the higher the intensity of communication within the research organisation, the better the results of the research activities (Allen, 1970; Epton, 1981; Hauptman, 1986).

(4) Geographical Distances and Communication Intensity

Communication pattern researchers also highlighted the impact of the geographical separation of individuals upon the intensity of communication. The further the geographical distances between individuals, the lower the probability of communication (Allen, 1970; Hough, 1972; Walsh and Baker, 1972; Evans et al., 1974; Allen and Fustfeld, 1975; Hall and Ritchie, 1975; Epton, 1981; Tomlin, 1981). Therefore, it is essential for project members to keep together so as to ease the sharing of technical and project-related information.

(5) Team Tenure and Team Performance

Katz and Allen (1982) suggested that project group tenure also influences performance. They argued that on one hand the project group tenure increases the friendship among group members (a positive factor for intra-group communication) and on the other hand also increases the NIH ("Not Invented Here") syndrome (a negative factor for inter-functional communication) and this results in an inverted U-shaped relationship between group tenure and performance.

(6) Access to External Information and Performance

Besides communication patterns, other factors were believed to influence project performance. Empirical findings suggested that the opportunity of accessing external information sources may result in increased project performance (Allen, 1970; Dewhirst et al., 1978).

(7) Access to Internal Information and Performance

The opportunity to access internal information increases project performance (Dewhirst et al., 1978; Allen et al., 1980).

(8) The Gatekeeper Role and Team Size

In addition to Shotwell (1971) and Walsh and Baker (1972) who challenged the validity of the gatekeeper theory, Pruthi and Nagpaul (1978, 1979) provided a better explanation of why, in some circumstances, the gatekeeper role is implicit. Comparing the communication patterns in small and large project settings, they concluded that the validity of the gatekeeper role becomes diluted as the project group size decreases. In other words, the gatekeeper role is highly influential only when the project group is very large so that communications have been very complex requiring particular people to act as windows for information acquisition and transmission.

(9) Organisational Structure and Communication Patterns

Organisational structural settings were also found to influence communication patterns. Taylor and Utterback (1975) reported that changes in organisation structure tend to reduce technical communication both within the changed group and between the changed group and sources of technical information outside the organisation. Hall and Ritchie (1975) argued that it is not the geographical distances but the organisational structure that determines the frequency of communication. They asserted that the organisational structure decides friendship patterns among members and therefore decides communication patterns. Pruthi and Nagpaul (1978) also demonstrated that the individual's position in the organisational hierarchy and the working relationship between individuals both greatly influence communication patterns.

(10) Managerial Approaches and Communication Patterns

Griffin and Hauser (1992) in an article investigating the QFD (Quality Function Deployment) technique also alluded to the fact that communication patterns within a project group may vary according to the managerial approaches adopted.

(11) Project Types and Communication Patterns

Besides the structural factors, the nature of the project itself may also influence communication patterns. Holland et al. (1976) suggested that under highly uncertain situations it would be better for the project group to employ richer and more direct communication channels such as inter-personal communication for information transmission. Stevenson and Gilly (1991) also found that the more difficult and novel the problem to be solved, the more frequently informal communication channels should be employed. However, the above assertions about the problem type that influences communication patterns were not supported by Nagpaul and Pruthi (1979).

(12) Identifying Gatekeepers

Most scholars admit that Gatekeepers play a significant role in R&D. According to Nochur and Allen (1992), it is not necessary to nominate the boundary-spanners officially. Effective gatekeepers are formed naturally within an organisation because of their particular authoritative knowledge and personal connections.

In summary, the Communication Pattern studies stressed the role of communication in innovation. They pointed out that information acquisition and transmission, in essence, play the most critical part in the whole R&D process. However, as they concentrated too much on the technological side of communication they were not able to recognize the necessity of interactions with the marketplace. In addition, current technology development in computer networking and communication may weaken core concepts such as the gatekeeper role and geographical separation in Communication Pattern studies. As the theoretical foundations of this stream of studies were mainly constructed around the 1970s, they may not be able to reveal the nature of NPD in current social conditions.

2.5.3 *The Interface Studies*

Unlike the Communication Pattern studies that were looking principally at research laboratory management, the Interface studies stressed the role of integration and communication between different operational functions during NPD. Johnson and Jones (1956) stated the importance of better functional interfaces in facilitating product innovation. Later studies by Olin (1973) and Phelps (1977) supported the view that interface management led to more effective NPD. Moenaert and Souder (1990) and Pinto and Pinto (1990) empirically affirmed the positive associations between better functional interfaces and project outcome. Gupta et al. (1986) in addition asserted that the higher the environment uncertainty of a NPD project, the greater the need for functional integration.

However, interface management has never been a simple task. There are trade-offs between the short-term financial pressure from marketing and the long-term entrepreneurial goals of R&D members. It is also necessary to deal with the conflict between manufacturing and R&D. From the manufacturing viewpoint, the existing standardized product design is better for exploiting learning curve effects and meanwhile smoothing production. However, from the R&D perspective, the exploration of new technology and new design is the reason for its existence. In a major survey Souder (1987: 161-9, 1988: 8-11) concluded that there were at least five barriers to creating and maintaining better functional interfaces, i.e.,

- Distrust among functional groups,
- Lack of Appreciation,
- Too-Good Friends,
- Lack of Communication, and
- Lack of Interaction.

Interface scholars, however, suggest several guidelines for promoting harmony among functions. Table 2.4 presents a summary of these studies into interfaces between R&D and Marketing, Manufacturing, Top Management, and Purchasing. Twelve main facilitators of functional interface management were identified, i.e.,

Table 2.4 Summary of Interface Studies

Facilitators of Functional Interface	R&D with Marketing	R&D with Manufacturing	R&D with Top Management	R&D with Purchasing
Managerial Arrangement for Functional Integration	Shanklin and Ryans, Jr. (1984: Empirical, N=125); Bonnet (1986: Empirical, N=23); Gupta and Wilemon (1988: Empirical, N=80); Souder (1987, 1988: Empirical, N=289); Gupta and Wilemon (1990: Empirical, N=83); Song and Parry (1993: Empirical, N=274); Moenaert et al. (1994: Empirical, N=78)	Bergen (1982: Empirical, N=33); van Dierdonck (1990: Theoretical)	Eschenbach and Geistauts (1987: Theoretical); Good (1991: Single Case study)	
Structural Redesign for Functional Integration	Bonnet (1986: Empirical, N=23); Gupta and Wilemon (1988: Empirical, N=80); Souder (1987, 1988: Empirical, N=289); Song and Parry (1993: Empirical, N=274); Moenaert et al. (1994: Empirical, N=78)	Thurmond and Kunak (1988: Theoretical); van Dierdonck (1990: Theoretical)	Gupta and Wilemon (1990: Empirical, N=83)	
Promoting and Maintaining Social Interactions and Communications	Shanklin and Ryans, Jr. (1984: Empirical, N=125); Souder (1987, 1988: Empirical, N=289); Pinto and Pinto (1990: Empirical, N=262)	Bergen (1982: Empirical, N=33); Bergen and Miyajima (1986: Empitical, N=42); van Dierdonck (1990: Theoretical)	Gupta and Wilemon (1990: Empirical, N=83); Good (1991: Single Case study)	
Providing Specific Information to Each Other	Gupta et al. (1985: Empirical, N=216); Bonnet (1986: Empirical, N=23); Carlsson (1991: Empirical, N=57); Song and Parry (1992: Empirical, N=264)	Carlsson (1991: Empirical, N=57)		Burt and Soukup (1985: Theoretical)
Utilising Integrated Information Systems		Rothwell and Whiston (1990: Theoretical); de Meyer (1990: Empirical, N=75); de Meyer and van Hooland (1990: Empirical, N=174)		
Better Information Quality and Credibility	Gupta and Wilemon (1988: Empirical, N=80); Gupta and Wilemon (1990: Empirical, N=83); Song and Parry (1993: Empirical, N=274)			

Table 2.4 (Continued)

Facilitators of Functional Interface	R&D with Marketing	R&D with Manufacturing	R&D with Top Management	R&D with Purchasing
Possitive Attitude Toward Interface Problems	Gupta and Wilemon (1986: Theoretical); Souder (1987, 1988: Empirical, N=289); Gupta and Wilemon (1990: Empirical, N=83)			
Involvement and Commitment to Project	Souder and Chakrabarti (1979: Empirical, N=116)		Urban et al. (1987: Textbook, p.298); Thurmond and Kunak (1988: Theoretical); Gupta and Wilemon (1990: Empirical, N=83); Hamilton and Mitchell (1990: Theoretical)	
Absence of Status-Consciousness Between Each Other	Souder and Chakrabarti (1979: Empirical, N=116)	Bergen (1982: Empirical, N=33); van Dierdnock (1990: Theoretical)	Good (1991: Single Case study)	
Participating In a Particular Task Together	Souder and Chakrabarti (1978: Empirical, N=117); Shanklin and Ryans, Jr. (1984: Empirical, N=125); Gupta et al. (1985: Empirical, N=216); Hise et al. (1990: Empirical, N=252); Carlsson (1991: Empirical, N=57); Song and Parry (1992: Empirical, N=264); Song and Parry (1993: Empirical, N=274)	Bergen and Miyajima (1986: Empitical, N=42); Thurmond and Kunak (1988: Theoretical); Carlsson (1991: Empirical, N=57)	Urban et al. (1987: Textbook, p.298)	Burt and Soukup (1985: Theoretical)
Implementing Particular Programmes/Tools Designed for Better Interface Manageemnt	Gupta and Wilemon (1986: Theoretical); Souder (1987, 1988: Empirical, N=289); Gupta and Wilemon (1990: Empirical, N=83); Griffin and Hauser (1992: 2 case studies)	Griffin and Hauser (1992: 2 case studies)		
A More Flexible/Looser Control Mechanism	Gupta and Wilemon (1986: Theoretical); Song and Parry (1993: Empirical, N=274)	Bergen (1982: Empirical, N=33)	Bergen (1982: Empirical, N=33)	

- Managerial arrangement for functional integration,
- Structural redesign for functional integration,
- Promoting and maintaining social interactions and communications,
- Providing specific information to one another,
- Utilising integrated information systems,
- Better information quality and credibility,
- Positive attitude towards interface problems,
- Involvement and commitment to project,
- Absence of status-consciousness between one another,
- Participating in a particular task together,
- Implementing particular programmes/tool which was designed for better interface management, and
- A more flexible/looser control mechanism.

It is clear that the key appeals in the Interface studies were the promoting of functional information transmission, communication, and corporation during NPD, especially, the enhancing of relationship between R&D and Marketing. Several specific tasks and particular types of information were identified as key areas for functional integration. A variety of managerial programmes was also developed and suggested for facilitating functional consensus and team spirit. For example, the joint efforts of R&D and Marketing in identifying market needs and designing user/service manuals were repeatedly found to contribute to project success (Gupta et al., 1985; Song and Parry, 1992). The employment of "Nominal-Interacting Group" (Souder, 1987), "Joint Reward Systems" (Gupta and Wilemon, 1990; Song and Parry, 1993) and "Quality Function Deployment Programme" (Griffin and Hauser, 1992) were also suggested to encourage functional value sharing and co-operation. The main theme underlying these activities was the belief that NPD is essentially a multi-disciplinary team-based effort. It is an integrated system that accommodates internal technology competencies, strategic views, and logistic capabilities as well as external market needs.

These studies did show the role of functional communication and integration during product innovation. However, their focus on only functional information transmission and integration during NPD is rather incomplete. Continual and sustained innovation is also a learning system. If learning is part and parcel of successful NPD, then another challenge facing management is handling the complexity and difficulty of knowledge creation, internalisation, accumulation, and utilisation. Communication effectiveness is an important element in the innovation learning process. Therefore, an appreciation of its impact on new product outcome remains relevant to NPD researchers. These will further be discussed in the following sections about Japanese practices and Organisational Learning studies.

2.5.4 *Japanese NPD Practices*

The outstanding achievement of Japanese economic strength in the last two or three decades led many scholars to investigate the secret of Japanese corporate success. For NPD, studies first recognised the astonishing quality and productivity of Japanese manufacturing in the 70s and the early 80s. Later more attention focused on the threat from Japanese high-tech innovativeness and improvements in research capabilities in the late 80s and 90s. Drucker (1971) was among the first western writers to try to reveal the Japanese success formula. He concluded that the reasons for Japanese excellence stemmed from their long term perspective, their willingness to accept change, and their enthusiastic drive for productivity and quality.

Subsequent studies mostly inherited a similar "soft" view that Japanese success was a result of appropriate overall managerial efforts rather than the "hard" techniques or skills (Cole, 1971, 1980; Drucker, 1981; Hayes, 1981). However, these early assertions were fragmentary and mainly focused on revealing the proficiency of Japanese style manufacturing. One of the exceptions was Ouchi et al. (1978) and Ouchi (1981) who coined "Theory Z". Theory Z was in effect a summary of Ouchi's work about Japanese managerial approaches in the 1970s and may be regarded as a landmark that distinguished between early and later research into Japanese business practices. Theory Z proposed two basic ideas underlying Japanese management. Firstly, Japanese firms are keen to promote and maintain high quality integration/co-operation with their external partners so as to reduce the value-added costs and increase the efficiency of the total value chain. Secondly, Japanese firms appreciate the value of individuals and tend to rely on team autonomy to manage their manufacturing organisation.

In considering the overwhelming global success of Japanese high-tech industries in the 1980s, more recent Japanese management studies focused on investigating Japanese technological progress and R&D efforts. These studies were mainly based on general observations of phenomena or case studies of Japanese firms and were very often disorganized, lacking both strong theoretical and empirical bases. However, these studies did reveal several key concepts about Japanese R&D management. Figure 2.6 presents a summary of these key concepts derived from the studies of Japanese companies.

At centre of this framework are the five general factors directly associated with Japanese NPD excellence: (1) the design memory, (2) knowledge creating, (3) the project control mechanism, (4) NPD strategy, and (5) other non-NPD factors. Although the key ideas in Japanese NPD practices were collectively cited from previous studies, these five major factors and their subordinate variables are, in effect, inter-related, making simultaneous impact upon Japanese NPD excellence.

The Design Memory

Unlike their western counterparts that are eager merely in pursuing new technological breakthroughs, Japanese firms concentrate their efforts on maintaining design memory. Ealey and Soderberg (1990) stated that both the "hardware" (i.e., expert systems, design databases, and design networking) and the "humanware" (i.e., the managerial arrangement for human factors) are crucial in maintaining an organisation's design memory. By observing the NPD activities in Honda, they concluded that human factors such as career paths, appreciation of humanity, level of team autonomy, and team structure play the key role in NPD. For example, they reported that Honda has established a career tracking system for technical experts, so that one can be promoted to a very high position in the organisational hierarchy exempt from any supervisory responsibility. Therefore the researchers can continuously and securely devote themselves to the life-time career of technological development.

In addition to the career path arrangement, there are more Japanese managerial efforts that sought to provide better humanware for NPD. The most frequently cited arrangements include the following:

Figure 2.6 Key Concepts Derived from Japanese NPD Practices

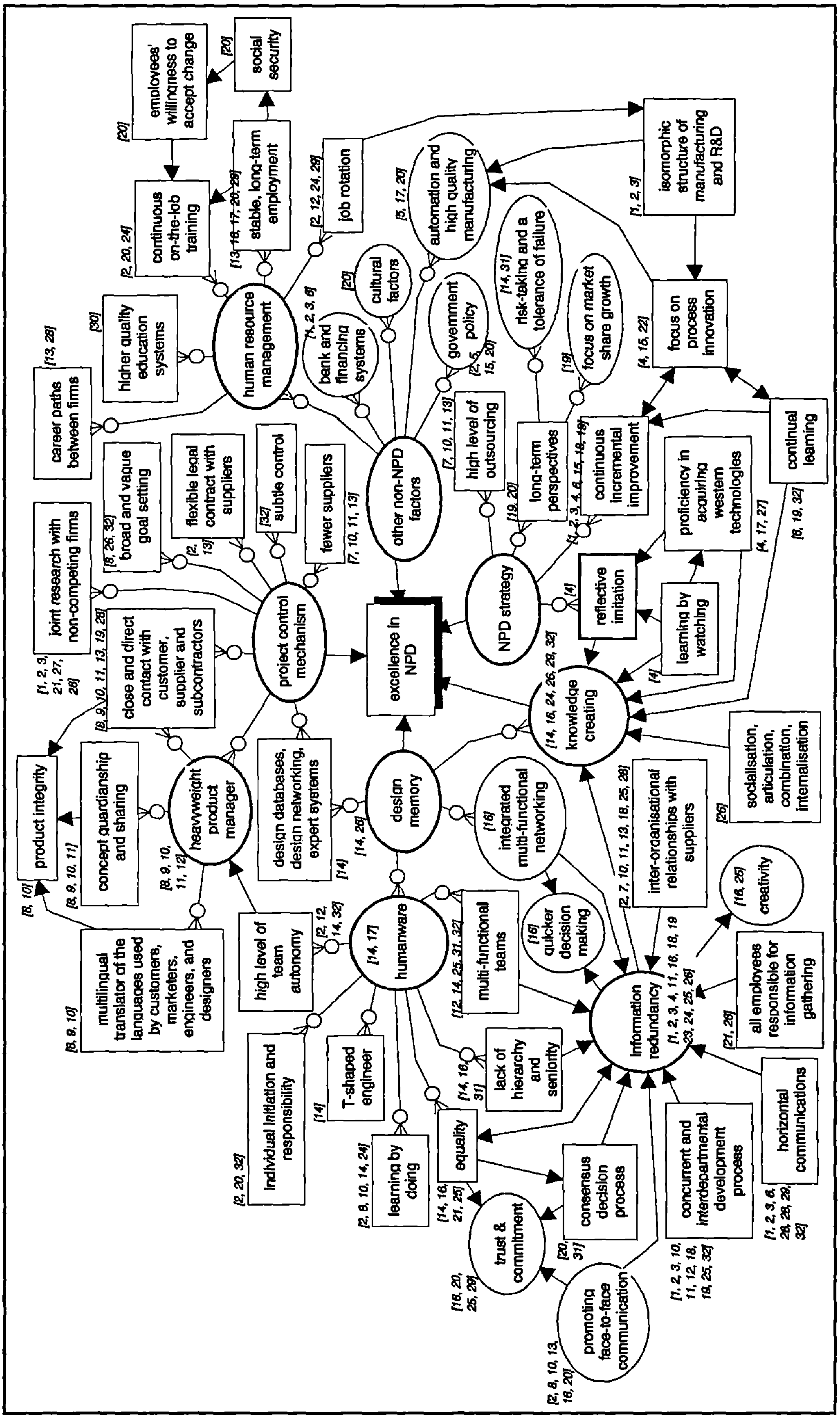


Figure 2.6 (Continued)

The concepts presented in the diagram are derived from the following sources:

[1] Aoki (1986); [2] Aoki (1988); [3] Aoki (1990); [4] Bolton (1993); [5] Bowonder and Miyake (1991); *[6] Bowonder and Miyake (1992ab); [7] Clark (1989); [8] Clark and Fujimoto (1990)*; [9] Clark and Fujimoto (1991a); [10] Clark and Fujimoto (1991b); [11] Clark et al. (1987); [12] Collinson (1993); [13] Dyer and Ouchi (1993); [14] Ealey and Soderberg (1990); [15] Fukasaku (1991); [16] Ghoshal and Butler (1992); [17] Harber and Samson (1989); [18] Imai et al. (1985); [19] Kennard (1991); [20] Keys and Miller (1984); [21] Kodama (1992); [22] Kotabe (1990); [23] Kuo and Hsu (1990); [24] Nonaka and Johansson (1985); [25] Nonaka (1990); [26] Nonaka (1991); [27] Roberts and Mizouchi (1989); [28] Samuels (1994); [29] Smothers (1990); [30] Speiser (1988); [31] Song and Parry (1993); [32] Takeuchi and Nonaka (1986).

(1) Multi-Functional Teams (Collinson, 1993; Ealey and Soderberg, 1990; Nonaka, 1990; Song and Parry, 1993; Takeuchi and Nonaka, 1986),

(2) Learning and Training Through Real-World Situations (Aoki, 1988; Clark and Fujimoto, 1990, 1991b; Ealey and Soderberg, 1990; Nonaka and Johansson, 1985),

(3) Equality Among All Members (Ealey and Soderberg, 1990; Ghoshal and Butler, 1992; Kodama, 1992; Nonaka, 1990),

(4) Lack of Hierarchy and Seniority (Ealey and Soderberg, 1990; Ghoshal and Butler, 1992; Song and Parry, 1993),

(5) Individual Initiation and Responsibility (Aoki, 1988; Keys and Miller, 1984; Takeuchi and Nonaka, 1986), and

(6) High Level of Team Autonomy (Aoki, 1988; Collinson, 1993; Ealey and Soderberg, 1990; Takeuchi and Nonaka, 1986).

These managerial arrangements alone are believed to contribute much in constructing better humanware and therefore they are able to improve design memory. Moreover, their compound effects also benefit the project teams. For instance, the promoting of equality among members provides a sound atmosphere for trust and commitment, and this further enhances team spirit during NPD (Ghoshal and Butler, 1992; Nonaka, 1990). Finally, the focus of Japanese experiences on "humanware" does not mean the "hardware" side is not important. On the contrary, the Japanese firms have been very keen in accepting and acquiring new technologies, hardwares, and anything that can boost the maintaining of design memory. A case study of the Kao Corporation, for example, clearly described the benefits of integrated multi-functional computer networking in accelerating information acquisition, transmission, utilisation, decision making, and the updating of their design memory (Ghoshal and Butler, 1992).

Knowledge Creation

Knowledge Creation is another important phenomenon in Japanese NPD practices (Ealey and Soderberg, 1990; Ghoshal and Butler, 1992; Nonaka and Johansson, 1985; Nonaka, 1991; Smothers, 1990; Takeuchi and Nonaka, 1986). New product development, from their viewpoint, is something to do with the continuous creating, enlarging, and retrieving of design memory. To some extent, it does highly correlate with the ability to acquire and utilize information. However, to the successful Japanese firms proficiency in information gathering alone is not enough to create, as well as to maintain, design memory. They seek better management of information transmission, accumulation, and digestion, that is, the management of design knowledge.

Three major concepts underlie the management of design knowledge, i.e., the orientation of technology progress, the approach for information transmission, and the process of information digestion and knowledge creation. The proficiency of Japanese firms in acquiring western technologies has long been recognised as a key factor of Japanese NPD competence (Bolton, 1993; Harber and Samson, 1989; Roberts and Mizouchi (1989). However, in addition to their keen technology transferring and core technology developing efforts, the key capabilities that contribute to Japanese success are continual learning (Bowonder and Miyake, 1992ab; Kennard, 1991; Takeuchi and Nonaka, 1986) and continuous incremental improvement in both product and process innovations (Aoki, 1986, 1988, 1990; Bolton, 1993; Bowonder and Miyake, 1992ab; Fukasaku, 1991; Imai et al., 1985; Kennard, 1991). Bolton (1993) labelled such learning and improving "learning by watching". Such a continuous and incremental approach to innovation was believed the major reason for the better position of Japanese firms in fast-moving industries (Bolton, 1993).

Japanese style information transmission and utilisation was best described by Nonaka (1990: 28) as "Information Redundancy":

> *Information redundancy refers to a condition where some types of excess information are shared in addition to the minimal amount of requisite information held by every individual, department (group), or organization in performing a specific function. While this excess information could be considered needless or superfluous from a standpoint of efficiently processing information in quantity, from a qualitative standpoint this excess information enriches the meaningful functions of the organization.*

Despite the variety of terminology used by different writers, previous studies shared a similar observation that Japanese firms encourage information sharing and diffusion across the corporation (Aoki, 1986, 1988, 1990; Bolton, 1993; Clark et al., 1987; Ghoshal and Butler, 1992; Imai et al., 1985; Kennard, 1991; Kuo and Hsu, 1990; Nonaka and Johansson, 1985; Nonaka, 1990, 1991). Especially "horizontal communications" are greatly promoted to break the barrier between functional departments (Aoki, 1986, 1988, 1990; Bowonder and Miyake, 1992ab; Nonaka, 1991; Samuels, 1994; Smothers, 1990; Takeuchi and Nonaka, 1986). Many structural factors have contributed to such information redundancy, including,

- the employment of multi-functional teams (Collinson, 1993; Ealey and Soderberg, 1990; Nonaka, 1990; Song and Parry, 1993; Takeuchi and Nonaka, 1986),
- the presence of concurrent and interdepartmental development process (Aoki, 1986, 1988, 1990; Clark and Fujimoto, 1991b; Clark et al., 1987; Collinson, 1993; Imai et al., 1985; Kennard, 1991; Nonaka, 1990; Takeuchi and Nonaka, 1986),
- the lack of hierarchy and seniority (Ealey and Soderberg, 1990; Ghoshal and Butler, 1992; Song and Parry, 1993),
- the use of a consensus decision process (Keys and Miller, 1984; Song and Parry, 1993),
- inter-organisational relationships with suppliers (Aoki, 1988; Clark, 1989; Clark and Fujimoto, 1991b; Clark et al., 1987; Dyer and Ouchi, 1993; Imai et al., 1985; Nonaka, 1990; Samuels, 1994), and
- integrated multi-functional networking (Ghoshal and Butler, 1992).

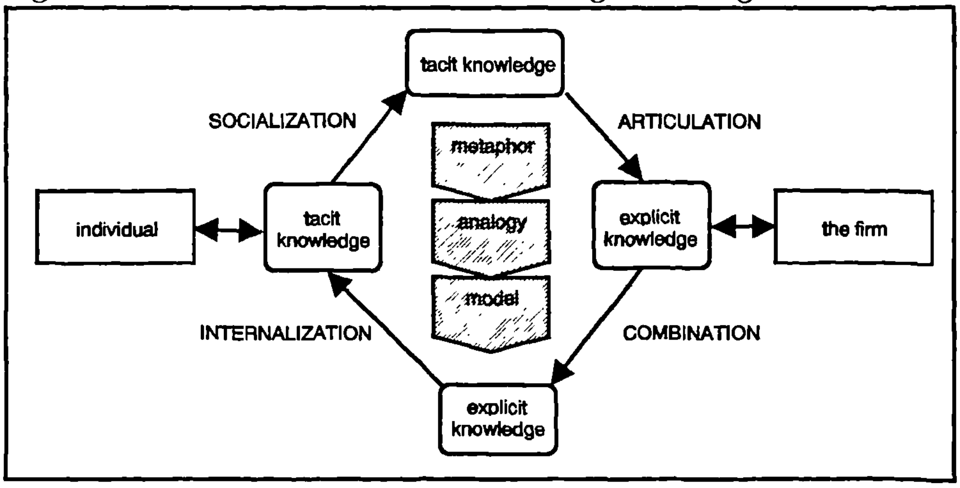
Kodama (1992) and Nonaka (1991) also suggested that employees' commitment to, and self-initiated responsibility for, information gathering are other facilitators for information redundancy. The promoting of face-to-face communication inside and outside the organisation may also be very useful in fostering richer information transmission (Aoki, 1988; Clark and Fujimoto, 1990; Clark and Fujimoto, 1991b; Dyer and Ouchi, 1993; Ghoshal and Butler, 1992; Keys and Miller, 1984).

Information accumulation and assimilation are the focal considerations in knowledge creating. Nonaka (1991) summarised the industrial innovation experiences from Honda, Canon, Matsushita, NEC, Sharp, and Kao and provided a clear picture of how these highly successful Japanese firms manage information digestion and accumulation. Figure 2.7 presents a framework with several key concepts that are derived from Nonaka (1991)'s work. Nonaka asserted that knowledge is the key source for companies to sustain a long lasting competitiveness in this uncertain age. He said that knowledge creating was a process of information/knowledge transformation from individual tacit knowledge to firm-level explicit knowledge, and finally to everyone's tacit knowledge within the firm. At the heart of his model is the mechanism that transforms information and knowledge, i.e., socialisation, articulation, combination, and internalisation. He also suggested that Japanese project teams were especially proficient in exploiting tools such as metaphors, analogies, and models to consolidate new product ideas and translate these into actual products.

The Project Control Mechanism

Japanese firms also show significant differences from their western counterparts in terms of project control mechanism. Unlike western style project management which prefers a clear and detailed goal from the very beginning, the Japanese project often starts from a broad and vague idea provided by top management (Clark and Fujimoto, 1990; Nonaka, 1991; Takeuchi and Nonaka, 1986). Having only a rough instruction about R&D direction, the NPD team therefore enjoys a great degree of freedom and autonomy during concept development and prototyping. This guarantees a thorough utilisation of individuals' creativity. The willingness for continual learning, commitment to the project, and a spirit of self-initiation also play key roles in the NPD process.

Figure 2.7 Nonaka Model of Knowledge Creating



Source: Concepts derived from Nonaka (1991) and organised by the current study.

A concurrent interdepartmental development process (Aoki, 1986, 1988, 1990; Clark and Fujimoto, 1991b; Clark et al., 1987; Collinson, 1993; Imai et al., 1985; Kennard, 1991; Nonaka, 1990; Takeuchi and Nonaka, 1986) and "subtle control" (Takeuchi and Nonaka, 1986) are also basic characteristics of Japanese style project management. Such control mechanism, unlike western style large and detailed project planning which is mainly based on individual responsibilities and performance measures, is largely accomplished by team-based "self-control", "control through peer pressure", and "control by love" of multi-functional groups (Takeuchi and Nonaka, 1986).

The Japanese firms also prefer to establish long lasting and close relationships with few carefully selected suppliers rather than independently choosing from a long list of possible suppliers for each project (Clark, 1989; Clark and Fujimoto, 1991b; Clark et al., 1987; Dyer and Ouchi, 1993). Such a relationship between the manufacturer and its suppliers is often developed under inter-organisations and inter-CEOs friendship, trust, and commitment (Aoki, 1988; Clark, 1989; Clark and Fujimoto, 1991b; Clark et al., 1987; Dyer and Ouchi, 1993; Imai et al., 1985; Nonaka, 1990; Samuels, 1994). Their legal contracts concerning the transactions are also often very general and flexible (Aoki, 1988; Dyer and Ouchi, 1993). The written documents are not regarded as so important as those of their western counterparts. It is the "relationship" that matters. Perhaps this is due to the situation that many top managers in the supplier firms are often the former employees of the manufacturer (Dyer and Ouchi, 1993; Samuels, 1994).

Another key feature of Japanese style NPD is the concept of "heavyweight product manager" (Clark and Fujimoto, 1990, 1991ab; Clark et al., 1987; Collinson, 1993). A heavyweight product manager is a project leader who is granted complete authority, autonomy, and responsibility for a particular NPD project. He is normally the person who consolidates the product concept and acts as a concept guardian, always keen to protect and share the concept with everyone (Clark and Fujimoto, 1990, 1991ab; Clark et al., 1987). He is also enthusiastic in keeping close and direct contact with customers, suppliers, and subcontractors outside the firm as well as the marketers, engineers, designers, and the assembly line workers within the company (Clark and Fujimoto, 1990, 1991ab; Clark et al., 1987; Dyer and Ouchi, 1993; Kennard, 1991; Samuels, 1994). Clark and Fujimoto (1990, 1991ab) described the heavyweight product manager also as the multilingual translator fluent with the languages used by customers, marketers, engineers, and designers. He is the man who bridges the needs of the marketplace and the competency of the R&D and therefore accomplishes a high level of product integrity (Clark and Fujimoto, 1990; Clark and Fujimoto, 1991b).

NPD Strategy

Japanese strategic orientation also largely departs from that of their western competitors. The most obvious difference is their long-term perspective. Keys and Miller (1984) suggested that Japanese firms place more emphasis on long-run planning and activities such as the commitment of sufficient time to managers, development of an integrated organisational philosophy, executive investment in employee training and development and so on. Kennard (1991) compared the differences of business priorities between the U.S. and the Japanese firms and found that Japanese firms were more eager in pursuing long term achievements such as market share increase or new product ratio and were less concerned about the short term indexes such as share price increase or debt/equity ratio.

Another important NPD strategic choice is the high level of out-sourcing of black-box parts and subcontracting of design tasks (Clark, 1989; Clark and Fujimoto, 1991b; Clark et al., 1987; Dyer and Ouchi, 1993). These phenomena are consistent with other traditional Japanese management concepts, such as the strong linkage of the manufacturer with their suppliers and subcontractors (Aoki, 1988; Clark, 1989; Clark and Fujimoto, 1991b; Clark et al., 1987; Dyer and Ouchi, 1993; Imai et al., 1985; Nonaka, 1990; Samuels, 1994). The Japanese firms are well-organized troops. They attack their enemy by the power of extensive corporations rather than by isolated individual heroes.

Finally Bolton (1993) concluded that the Japanese success can be largely attributed to their proficiency in "reflective imitation". She defined such kind of imitation as a process of learning by watching, adaptation, and modification that requires both internal development competencies and external technology intelligence. It is clear that the proficiency of Japanese firms in acquiring western technologies (Bolton, 1993; Harber and Samson, 1989; Roberts and Mizouchi, 1989), their focus on process innovation (Bolton, 1993; Fukasaku, 1991; Kotabe, 1990) and continual learning (Bowonder and Miyake, 1992ab; Kennard, 1991; Takeuchi and Nonaka, 1986), and their commitment to continuous incremental improvement (Aoki, 1986, 1988, 1990; Bolton, 1993; Bowonder and Miyake, 1992ab; Fukasaku, 1991; Imai et al., 1985; Kennard, 1991) play key roles in making this strategy possible.

Other Non-NPD Factors

Many scholars argued that Japanese success in product innovation is largely due to its unique culture (Keys and Miller, 1984), traditions (Dyer and Ouchi, 1993; Ghoshal and Butler, 1992; Harber and Samson, 1989; Keys and Miller, 1984; Smothers, 1990), and aggressive national technology policies (Aoki, 1988; Bowonder and Miyake, 1991; Fukasaku, 1991; Keys and Miller, 1984). Japanese banking systems along with government support provide sufficient long-term funding for high risk and time consuming product innovations and research (Aoki, 1986, 1988, 1990; Bowonder and Miyake, 1992ab). As a result, Japanese firms are able to concentrate their efforts on long-term strategic planning and implementation.

The Japanese "life time" employment tradition also contributes to its NPD excellence (Dyer and Ouchi, 1993; Ghoshal and Butler, 1992; Harber and Samson, 1989; Keys and Miller, 1984; Smothers, 1990). A stable and long-term employment policy strongly provides the necessary security to employees (Keys and Miller, 1984) and consequently encourages both the employer's willingness to carry out continuous on-the-job training (Aoki, 1988; Keys and Miller, 1984; Nonaka and Johansson, 1985) and the employees' acceptance of learning and technological change (Keys and Miller, 1984). The relatively harmonious industrial relationships and less powerful unions, in contrast to those found in western countries, to some extent reflect such a situation.

The establishment of manufacturing competence and the insistence on continuous process innovation are also key factors in deciding Japanese R&D success. From a hardware perspective, the Japanese have been very keen adopters of industrial robots and automation techniques in their drive to improve manufacturing productivity and quality (Bowonder and Miyake, 1991; .Harber and Samson, 1989; Keys and Miller, 1984). These efforts further increase the speed and quality of prototyping and pilot runs during NPD. From the humanware perspective, Japanese social traditions and educational systems impose on students a strong positive attitude toward technology and an intensive study habit early in their college years. This guarantees the quantity and also the quality of necessary scientific researchers and technological engineers (Speiser, 1988). Furthermore, firms' policy of frequent job rotation (Aoki, 1988; Collinson, 1993; Nonaka and Johansson, 1985; Smothers, 1990), the career paths between manufacturer and supplier firms (Dyer and Ouchi, 1993; Samuels, 1994) , and the isomorphic structure of manufacturing and R&D within the corporation (Aoki, 1986, 1988, 1990) provide employees with opportunities for establishing multi-discipline experiences.

In summary, Japanese innovation studies have displayed the general ingredients for success behind the most innovative firms in the modern economy. However, the majority of these studies are based on personal observations or limited sample case studies, so greatly lack empirical and theoretical bases. In addition, as many scholars have claimed, the cultural differences between East and West have caused difficulty in transferring Japanese experiences to the rest of the world (Sullivan, 1983; Jones, 1992). Even so, many writers argue that, although there are great differences in terms of cultural factors, there are general rules which can be identified as having important lessons for western managers (Ouchi and Jaeger, 1978; Pascale and Athos, 1981; Weiss, 1984). Some scholars utilized western Organisational Learning theory to address the underlying reason for Japanese NPD excellence (e.g., Nonaka and Johansson, 1985). These efforts will be discussed in the next section.

2.5.5 *Organisational Learning Studies*[5]

As stated in Section 2.5.4, scholars observed that the reason for Japanese innovation competence can be attributed to their proficiency in knowledge creation, accumulation, and assimilation (Nonaka and Johansson, 1985; Takeuchi and Nonaka, 1986; Ealey and Soderberg, 1990; Nonaka, 1990, 1991; Ghoshal and Butler, 1992). Many unique characteristics in Japanese management were believed to be particularly suitable for facilitating the process of organisational learning (Nonaka and Johansson, 1985). Western expertise in organisational learning therefore was borrowed as a theoretical support for explaining Far East NPD excellence (Nonaka and Johansson, 1985; Takeuchi and Nonaka, 1986; Ghoshal and Butler, 1992).

It was gradually accepted that the organisational learning phenomenon was the process of organisational adaptation, action-outcome recognition, knowledge/experience sharing and institutionalisation, and the self-correction of "theory-in-use" (March and Olsen, 1975; Mitroff and Emshoff, 1979; Argyris, 1977, 1986, 1991; Argyris and Schön, 1978; Hedberg, 1981; Diamond, 1986; Senge, 1990; Ngwenyama, 1991; McGill et al., 1992; Garvin, 1993; Kim, 1993; Schein, 1993). Garvin (1993: 80) defined a learning organisation as:

> *. . . an organization skilled at creating, acquiring, and transferring knowledge, and at modifying its behavior to reflect new knowledge and insights.*

Clearly, the organisational learning process can be distinguished as two-fold, i.e., the "learning" and the "unlearning" parts. For the "learning" part of the organisational learning process, organisation foci on creating and maintaining aggregated knowledge so as to strengthen its core capabilities (Leonard-Barton, 1992a). Argyris (1977, 1986, 1991) and Argyris and Schön (1978) called such activities "single-loop learning". Under "single-loop learning", an organisation learns by means of its long established values (i.e., theory-in-use) and the validity of the theory is "tested by [its] effectiveness in achieving the values [the organisation] hold (Argyris, 1977: 119)." For the "unlearning" part, the organisational learning theory argued the necessity of rethinking the "theory-in-use". As suggested by Leonard-Barton (1992a: 118), "values, skills, managerial systems, and technical systems that served the company well in the past and may still be wholly appropriate for some projects or parts of projects, are experienced by others as core rigidities -- inappropriate sets of knowledge." Therefore organisation is necessary to verify its values, assumptions, and knowledge domains continuously so as to bridge the discontinuity of technological progresses and environmental dynamics. This activity is also known as "double-loop learning", as first labelled by Argyris (1977).

Innovative Japanese firms appear to have efficiently exploited the "learning" part of organisational learning theory, while the "unlearning" part of theory was mainly developed and discussed by the western scholars. However, these discussions of organisational "unlearning" were mainly focused on the development of general organisation theories rather than NPD management (Argyris, 1977, 1986, 1991; Argyris and Schön, 1978; Diamond, 1986; Ngwenyama, 1991; Kim, 1993). Even though some studies did stress the need of "organisational unlearning" for NPD management, these studies have hardly provided insight into how firms might achieve such "unlearning". For example, by focusing on the dimensions of organisational skills, technical systems, managerial systems, and values, Leonard-Barton (1992a) described how the core capabilities of an organisation can also inhibit innovation. Although he argued strongly that organisations should continuously challenge their current paradigms so as to manage the paradox between core capabilities and core rigidities, he did not provide any prescription for coping with this situation.

Figure 2.8 is a simplified organisational learning model for managing product innovation. The whole process is divided into two basic modes of learning, i.e., the single-loop and the double-loop learning (Argyris, 1977, 1986, 1991; Argyris and Schön, 1978. For the single-loop learning, knowledge acquisition begins with individual learning efforts which translate a variety of internal and external information into personal tacit knowledge (Pavitt, 1990). With proper structural design, such individual tacit knowledge is shared with other people in the organisation by means of socialisation, articulation, combination, and internalisation (Nonaka, 1991). As a result, knowledge therefore can be stored within the organisation in the forms of documentation, procedures, systems, skills, norms, and values, explicitly or tacitly (Nonaka, 1991; Leonard-Barton, 1992a). These further construct the core capabilities of the organisation (Leonard-Barton, 1992a).

For double-loop learning, organisations should continuously rethink the validity of their current core capabilities (Leonard-Barton, 1992a). This requires a great degree of external integration and boundary expansion efforts (McKee, 1992; Leonard-Barton, 1992b). In the first place, organisations may provide their members with better incentives for boundary-spanning activities. Furthermore, organisation members may be freed to visit outside institutes for participating in joint-projects. More aggressively, outsiders (e.g., customers, suppliers, distributors, outside researchers) may be invited into the organisation for brain-storming of future opportunities, product concepts, and even technical solutions (McKee, 1992). These activities are necessary for enhancing an organisation's ability for self-discovery and easing the changing of its theory-in-use (Argyris, 1977).

A variety of managerial designs was believed to facilitate the organisational learning process. In addition to the Japanese NPD practices (see Section 2.5.4) which were particularly helpful in improving individual learning as well as corporate knowledge sharing, other scholars also provided insights for better managing single-loop learning. For example, performance rewards and egalitarianism were suggested as effective in promoting individual learning (Leonard-Barton (1992b). Computerisation, informal networking, communication rewards, job rotation, and multi-functional teams were highlighted as crucial in encouraging knowledge sharing (Meyers and Wilemon, 1989; McKee, 1992; de Meyer, 1993). On-the-job training/education and apprenticeships were also recognised as key instruments for experiences/technologies diffusion (Leonard-Barton, 1992b). To a greater or lesser extent, these issues also have been stressed in Japanese experiences.

Furthermore, there have been calls for fostering an organisation's boundary expansion and external integration. Leonard-Barton (1992b) stated that a positive attitude to risk taking and openness to knowledge from outside the organisation were the basic recipes for re-validating organisational memory. He also suggested that hiring practices, design of career paths, and resource allocation for alliances and networks may influence the effectiveness of double-loop learning. Finally, scholars reported that the mobility of R&D researchers (Goldberg et al., 1981), the policy of internationalising R&D (de Meyers, 1993), and close contacts between R&D and science communities (Henderson, 1994) also contributed to an organisation's external integration, which in turn, improved the organisation's capability of double-loop learning.

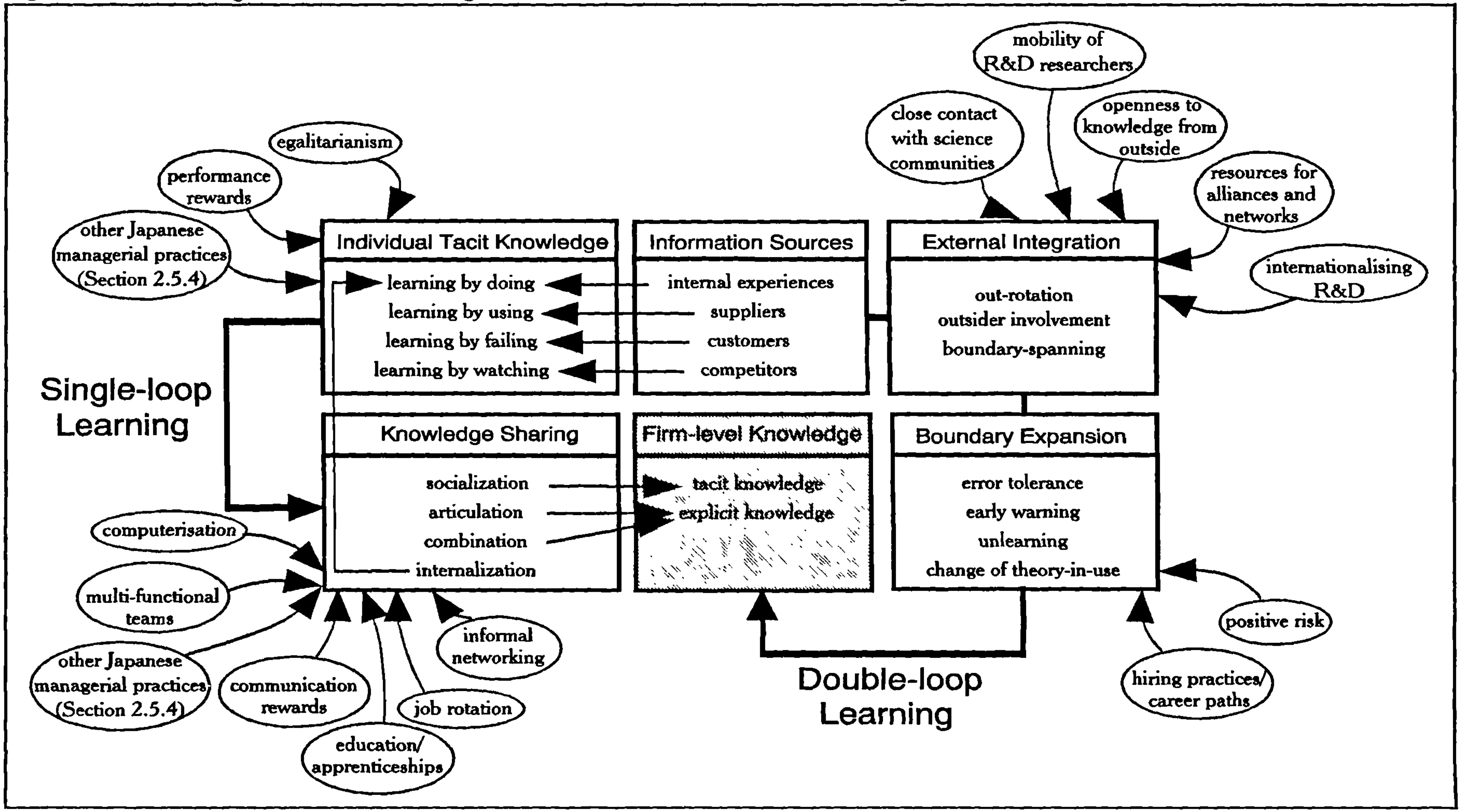
Above all, organisational learning studies have given insight into our understanding of the nature of product innovation. Although the early organisational learning theories recognised the interaction of organisation with its environment as one of the phenomena of the learning process (Cyert and March, 1963; Cangelosi and Dill, 1965; March and Olsen, 1975), the later development of the theory has been focused on the process of knowledge creation, maintenance, and validation within the firm (e.g., Argyris, 1977; Argyris and Schön, 1978; Hedberg, 1981; Nonaka and Johansson, 1985; Diamond, 1986; Nonaka, 1991; Walsh and Ungson, 1991; Garvin, 1993; Kim, 1993). The focus on learning within the firm does not necessarily deny the importance of environmental contingent factors. Nonaka (1991)'s promoting of the "knowledge creating company" was, in his words, based on the premise of a need to cope with a highly uncertain environment. This suggested that his assertions about Japanese managerial arrangements for better organisational learning may be largely contingent upon the environment.

To the author's knowledge, McKee (1992) may be the only writer who discussed organisational learning behaviour based on contingency model. He tried to theorize a linkage between new product types (i.e., a contingent variable) and the level of organisational learning (i.e., single-loop or double-loop learning) in an attempt to provide a contingency theory of organisational learning. Although he did provide detailed descriptions of both the organisational learning theory and the contingency theory, he did not show sufficient evidence to support the notion that incremental innovations should always be connected with single-loop learning and the discontinuous ones with double-loop learning. However, even with this drawback to his theory, it may be interesting to take a closer look at the contingency approach to NPD management. This will be discussed in Section 2.6.

2.5.6 Other Studies Concerning the Utilisation of Project Management Techniques and Information Systems

Except for the above approaches which tried to explain how a well managed product innovation process can result in better new product performance, there were other studies that

Figure 2.8 An Organisational Learning Model for Product Innovation Management



Source: Concepts derived from the following articles and organized by the current study: Argyris (1977); Nonaka and Johansson (1985); Takeuchi and Nonaka (1986); Meyers and Wilemon (1989); Pavitt (1990); Ealey and Soderberg (1990); Nonaka (1990, 1991); Ghoshal and Butler (1992); Leonard-Barton (1992b); McKee (1992); de Meyer (1993); Garvin (1993); Henderson (1994).

focused on the utilisation of "techniques" for improving NPD proficiency. This stream of work started from the early efforts of Operational Research studies around the time of the Second World War and later was developed into traditional project management techniques. These techniques, along with the fast advancement of computer technologies, were further programmed into computer softwares that can effectively and efficiently handle great amounts of complex project information. Moreover, with the maturity of Artificial Intelligence and Network Computing technologies in recent years, more highly intelligent project management tools have been developed. These tools, on the one hand, extract and represent the knowledge from project management experts, and on the other, provide opportunities for group participation in NPD decisions, thus facilitating organisational learning. The following is a very brief review of current progress in the development of these techniques.

Project Selection Techniques

The first comprehensive review of traditional project screening techniques may be the article written by Hall and Nauda (1990). Literature concerning project selection techniques from 1959 to 1988 was reviewed and categorised into four basic methodological approaches, namely:

(1) Mathematical Programming (i.e., constrained optimisation), which includes Integer Programming, Linear Programming, and Non-linear Programming;

(2) Cognitive Emulation Models, including Regression Models, Decision Tree Diagramming, Decision Process Models, and Expert Systems;

(3) *Ad Hoc* Methods, including Top-Down Methodologies, Genius Award, and System Approaches; and

(4) Benefit Measurement Methods, including Comparative Approaches, Scoring Models, and Benefit Contribution Models.

Fahrni and Spätig (1990) asserted that the employment of these screening techniques was dependent upon application-oriented contingencies. By summarising 18 types of project evaluation methods, together with 12 selection conditions, they suggested a "decision-tree" technique for choosing these methods. Their decision criteria were mainly concerned with the nature of projects such as how far the selection parameters can be quantified, the degree of interdependence between projects, single or multiple objectives of the projects, and the degree of acceptable risk involved.

Schmidt and Freeland (1992) suggested that the above traditional evaluation approaches were mostly based on optimization models, which in turn, largely ignored the importance of integration and participation of project-related members during the evaluation process. They argued that the commitment of members to the project was vital for its successful implementation, and such a commitment can only be fulfilled by means of sufficient discussion and interaction. They believed that such organisational decision behaviour was beyond the reach of optimisation methods.

Computer technologies have also been employed in project selection decisions. By accumulating more than 10 years of industrial experiences, R.G. Cooper's new product performance forecast model, NewProd, has been programmed into computer software for identifying high potential projects (Cooper, 1992). Unlike other optimisation methods, the NewProd system was designed to be used as a tool for multi-functional interaction in project-selection decision-making.

Ram and Ram (1989) adopted another approach for computerising project selection procedure. By acquiring and coding experts' knowledge about project evaluation into a knowledge base, they developed an expert system called INNOVATOR that can automatically judge whether to opt for a specific project or not in terms of the information given. INNOVATOR may be the first expert system designed particularly for project selection. However, it has yet to be fully validated.

Project Planning and Control Systems

Many investigators have sought to improve project planning and control mechanisms. There has been much debate concerning the entire project planning procedure (e.g., Fogg, 1976; Britton and Parker, 1993) and its relationship with corporate strategic planning (e.g., Adler et al., 1992). Literature also concentrated on better utilisation of tools (e.g., Watts and Higgins, 1987) in managing project scheduling (e.g., Dean et al., 1992), resource allocation (e.g., Cooper and Kleinschmidt, 1988; Granot and Zuckerman, 1991), and design quality (e.g., Clark and Fujimoto, 1990, 1991b).

The control of development time in particular has drawn great attention in recent years. Many scholars were eager to develop methods that can accelerate the new product development process so as to avoid product obsolescence (e.g., Gold, 1987; Cordero, 1991; Mabert et al., 1992; Millson et al., 1992). These techniques for collapsing development time may be summarized as follows:

(1) Team Composition, such as full-time team participation (Mabert et al., 1992), multi-functional team (Cordero, 1991), and early involvement of Marketing and Manufacturing functions (Gold, 1987; Mabert et al., 1992);

(2) Process Redesign, such as reliance on external sources of technology (Gold, 1987), and concurrent engineering (Cordero, 1991; Mabert et al., 1992; Millson et al., 1992);

(3) Working Methods Redesign, such as simplification of tasks, simplification of documentation, and reducing number of parts (Millson et al., 1992);

(4) Information Flow Redesign, such as regular formal meetings (Mabert et al., 1992), single allocation of team members (Cordero, 1991; Mabert et al., 1992), and creating of external alliances (Millson et al., 1992); and

(5) Employment of New Technology or Tools, such as PERT/CPM (Cordero, 1991; Millson et al., 1992), QFD (Cordero, 1991), CAD/CAE/CAPP/CAM (Cordero, 1991; Mabert et al., 1992; Millson et al., 1992), FMS/CIM/JIT (Cordero, 1991; Fjermestad and Chakrabarti, 1993), and simulated test markets (Cordero, 1991).

However, the acceleration of new product development also has its limitations or drawbacks. Millson et al. (1992) agreed that being too aggressive in reducing development time may result in a higher risk of inadequate market and financial estimation, poor documentation, unqualified testing, and may also lead to "group think". These will further downgrade development quality. Crawford (1992) in addition suggested that there were hidden costs of accelerated product development. For example, mistakes may happen when skipping certain steps and, in turn, more money is required to fix the problems. Therefore, it was suggested that firms should carefully consider this kind of acceleration strategy.

Computerised Information Systems

The rapid popularisation of computers in the last decades has brought great influences upon the way people manage development projects. In an early report, Karger and Murdick (1977) have described how they designed and constructed an information system for managing R&D activities. Binetti (1980) also provided a case study that highlighted how an on-line information retrieval system can greatly reduce the time spent in acquiring R&D related information. Another article written by Humphreys et al. (1983) showed how decision support systems can help to improve R&D decision quality. Even in those early days scholars had already recognised the potential power of computerised information systems in facilitating NPD.

Lee and Treacy (1988) stated that there were at least three reasons to implement information systems in NPD. First of all, it can provide better information supports to R&D members. Secondly, the high accessibility of information enhances the satisfaction of R&D members and therefore acts as a source of motivation. Finally, information systems provide effective analytical tools for helping the project management more efficiently. However, the utilisation of information technologies in NPD management has been largely influenced by the technological progress of the information industry. While computerised project management tools have been refined again and again (e.g., Coward et al., 1993), there are advancements in other areas that may revolutionally change the face of project management today. The most conspicuous examples may be the development of Artificial Intelligence and Computer Networking.

Batson (1987) suggested that because of the capability of decision support systems (DSSs) in dealing with unstructured problems in uncertain situations, DSSs may be the bridge to link the syndromes, frequently found in NPD, of the mismatch of information needs and the information systems employed. Buckner and Shah (1992) argued that the properly planned implementation of artificial intelligence systems can make ordinary workers become "knowledge workers". Even, remarkably, by using computer simulation techniques, the System Dynamics scholars at MIT further built a virtual "microworld" that claimed to be able to help policymakers "play-with" their knowledge/experiences in the interactive computer-based learning environment (Morecroft, 1987). Hence, the development of artificial intelligence technology not only improves project management quality but also provides a vehicle that accumulates and transfers project management experience/knowledge and therefore accelerates the learning process of project decision making.

Computer networking also provides great benefits to project management. The most promising development of computer networking to be used in the NPD sphere has been the invention of Groupware technology and the widely spread electronic mail networks. Groupware, workgroup computing or teamware, is a new technology that offers message sending and receiving, on-line discussion, central database sharing and co-editing, automatic group-scheduling, office automation, and document sharing simultaneously within computer networks (Eager et al., 1993; Powell and Ruley, 1994). Johnson (1994) reported, in a survey of 65 companies that have installed groupware for three years, that he found an average ROI of such investment of 179% and an average payback time of within 2.4 years. Scholars believed that the success of groupware technology/applications came from its ability to facilitate information/knowledge creating and sharing (Rein et al., 1993; Johnson, 1994) and therefore accelerate decision making (Fulmer, 1993). As suggested in Section 2.5.5, organisational learning is a very important nature of NPD. Such a learning process in essence greatly demands a high quality, as well as quantity, of knowledge creating and sharing. In that sense, groupware may be the best tool available that can guarantee the future needs of innovation management.

§2.6 The Design School Studies

The Design School studies held a contingent view of NPD management and highlighted that managerial efforts play a key role in securing project performance. The Design School studies asserted that organisations should adapt themselves to cope with the dynamics of contingent factors. They asserted that managerial efforts should be tailored (or designed) for a particular task so as to reflect the specific requirements embedded in the task and its incumbent environment. Among this stream of work, however, not all the writers highlighted a contingency approach in their research into innovation management. However, to a great extent, their research results implied that contingent factors moderate real-world NPD management activities.

At the firm-level perspective, contingent factors (e.g., environmental characteristics, the nature of the business, the nature of the firm) were found to be major determinants of strategic choices concerning corporate innovation policy (Horwitch and Thietart, 1987; Fritz, 1989; Capon et al., 1992). Kotabe (1990) reported that, as technological change is highly rapid in the marketplace, firms are required to invest more resources in process innovation to maintain their initial competitive advantage based on product innovation. Holak et al. (1991) found that a high level of R&D input will result in a high level of market share or profitability only when the firm is operating in an industry in which technological change is rapid. Bolton (1993) concluded that the choice of an innovation or an imitation product development policy is contingent upon incumbent industrial characteristics. She suggested that in an environment where property rights were not respected, where the employed technologies were highly interdependent, the industry was geared to high technical and market uncertainty, as well as rapid technological change, and when the firm has access to a rich knowledge base or information, imitators do well to use a learning-by-watching policy to leapfrog over the pioneers.

At the project-level, contingent factors also influenced innovation activities. Allen et al. (1980) asserted that the required level of inter-functional coordination was largely determined by the nature of the project. Gupta et al. (1986) highlighted that such a requirement of inter-functional coordination was also influenced by the nature of the project's incumbent environment. The greater the environmental uncertainty perceived by an organisation, the higher the need for inter-functional integration. Wong (1992) further suggested that functional strategies for new product introduction were contingent upon the stage the new product had reached in its industrial product life cycle (PLC). A tighter coordination of functional strategies was found to be greatly important for new products launched at the introductory or the maturity stage of their PLC, in contrast to the growth stage. Bryson and Bromiley (1993) stated that the general economic and political environment strongly influenced the aspects of project planning and implementation process and therefore indirectly determined project outcomes. Lee and Na (1994) reported that the internal project champion is meaningful only when the project is a radical one. This implies that the usefulness of certain NPD tools/techniques is probably dependent upon other contingent factors, rather than the tools/techniques themselves. More recently, Atuahene-Gima (1995) reported that firms producing incremental products tended to be more market-oriented, as opposed to those which producing radical innovations.

Indeed, previous studies have shown that the nature of task group mechanism for managing product innovation was determined by the characteristics of the project (Jermakowicz, 1978; Fischer, 1979; Tushman, 1979; Allen, 1986; Hauptman, 1986; Ito and Peterson, 1986; Shrivastava and Souder, 1987; Thurmond and Kunak, 1988; Brown and Karagozoglu, 1989; Fleischer and Liker, 1992; Shenhar, 1993; Keller, 1994), the project life cycle (Tushman, 1979; Johne, 1984; Rothwell et al., 1990; Rothwell, 1992), and the firm (McTavish, 1984), as well as the turbulence in the market (Tushman, 1979; Gupta et al., 1986; Shrivastava and Souder, 1987; Fleischer and Liker, 1992) and the technological environment (Holland et al., 1976; Souder, 1978; Allen, 1986; Shrivastava and Souder, 1987; Workman Jr., 1993). Table 2.5 is a summary of these studies. Contingent factors that influence managerial arrangements during product innovation can be categorised into five basic types, i.e., the nature of the technology employed, the nature of the incumbent environment, the characteristics of the project, project tenure, and project life cycle. In general, those successful projects that were regarded as highly radical or uncertain and which employed dynamic and rapid progressing technologies under an unstable or

Table 2.5 Summary of Design School Studies

Contingency Factors	Situations	Countermeasures	Sources
Nature of Technology Employed	relatively stable	employ project team structure	Allen (1986)
	dynamic	employ functional department structure	
	high technology	R&D dominant structure/system	Workman Jr. (1993)
	highly uncertain	direct, informal, and rich information transmission channels	Holland et al. (1976)
		in favour of task-dominant and process-dominant development models	Shrivastava and Souder (1987)
Nature of Incumbent Environment	stable	employ mechanistic structure	Tushman (1979), Fleischer and Liker (1992)
	unstable	employ organic structure	
	understandable	in favour of task-dominant development process	Shrivastava and Souder (1987)
	lack of understanding	in favour of stage-dominant development process	
	highly uncertain	require high inter-functional coordination	Gupta et al. (1986)
		in favour of task-dominant and process-dominant development models	Shrivastava and Souder (1987)
Characteristics of Project	routine task	require more coordination and control	Hauptman (1986)
		structure designed for greater efficiency and less information processing	Keller (1994)
		employ mechanistic structure	Tushman (1979), Fleischer and Liker (1992)
	nonroutine task	higher information needs	Hauptman (1986), Keller (1994)
		require more external information	Fischer (1979)
		require direct and informal communication channels	Keller (1994)
		employ organic structure	Tushman (1979), Fleischer and Liker (1992)
	highly uncertain project	require greater amount of information processing and communication channels	Keller (1994)
	incremental innovation	employ mechanistic structure, emphasize on internal information flow, external information only focus on market development	Jermakowicz (1978), Souder (1987), Thurmond and Kunak (1988), Brown and Karagozoglu (1989)
	radical innovation	employ informal and organic structure, emphasize on external information acquisition especially technical information	
	high technology project	flexible structure, enormous levels of communication, require informal interaction	Shenhar (1993)
	low technology project	formal managerial systems, formal communication	
		in favour of stage-dominant development process	Shrivastava and Souder (1987)
	highly difficult project	promote team autonomy, require more boundary spanning activities	Ito and Peterson (1986)
		in favour of task-dominant development process	Shrivastava and Souder (1987)
Project Tenure	short	employ project team structure	Allen (1986)
	long	employ functional department structure	
Project Life Cycle	later stages	employ mechanistic structure	Tushman (1979), Johne (1984), Rothwell et al. (1990), Rothwell (1992)
	early stages	employ organic structure	

turbulent environment were positively associated with the use of organic organisational structures, flexible and informal development processes, a greater amount of information needs, informal communication channels, and external information sources. The mechanistic structures and formal systems, on the other hand, favoured incremental projects conducted in a relatively stable environment.

Scholars therefore suggested a contingency approach to managing product innovation (Allen, 1986; Karagozoglu and Brown, 1993; Shenhar, 1993; Keller, 1994). They argued that NPD management should be carefully crafted or tailored in the context of the specific contingent situations of the particular project so as to implement innovation successfully. For example, Keller (1994) asserted a contingency approach to NPD management, based on the organisational information processing theory. He concluded that firms should adapt themselves to contingent factors such as the routineness or nonroutineness of project type while managing NPD information transmission. Allen (1986) also discussed the pros and cons of functional-based and project-based NPD structures. He asserted that the centralised R&D function better facilitates the sharing of technical knowledge among engineers, but it must pay the cost of higher difficulty in project coordination. On the other hand, the project-based structures offered better intra-project coordination but engineers would have higher risks of suffering from losing touch with scientific development. As a result, Allen suggested that the preferred structure is contingent upon new product situations. When the advancement of relevant scientific knowledge is rapid, or the development cycle of the project is long, functional-based NPD organisation generates the best project outcome. Otherwise, project-based structures are the better choice.

Although most scholars would more or less agree with the contingent view of product innovation management, to the author's knowledge, there is at least one article that formally goes against such a contingency approach of NPD. In a study concerning the Marketing/R&D interface during NPD, Hise et al. (1990: 154) argued that a tight integration of these two functions is the only universal rule of NPD management. Therefore, according to the writers, "... it is probably not beneficial for companies to modify their new product development strategies to accommodate different product subgroups." However, as their only contingent variable was the type of new product, i.e., the consumer or the industrial products, such a conclusion may not be valid for the whole spectrum of new product types.

In summary, the Design School of NPD studies has thrown light on our understanding of the interactions between contingent factors and innovation management practices. This stream of studies also has been strongly supported by the long-existing contingency theories from organisation studies[6]. However, most of these studies did not view contingent variables as the focal point of their research, although some of their empirical results did allude to the desirability of adopting a contingency approach to managing NPD. As a result, their definitions of contingent variables were relatively unstructured. Moreover, the discussions of NPD managerial practices in this stream of work were also very limited and mostly very abstract. Most scholars would discuss the design of a "mechanistic" or "organic" organisation structure, or the communication system that is "formal" or "informal". However, how, and to what extent, the informal or organic nature of the whole NPD system should be achieved was rarely mentioned.

§2.7 The Necessity of a More Integrated Model: Summary of Previous Research Approaches

This chapter reviewed about 350 articles and books on the topic of product innovation management. However, as there are limitations to the author's ability and time to acquire a greater amount of relevant materials, especially in non-English languages, the current study may still remain incomplete in its coverage of all the important studies concerning NPD management conducted worldwide. In addition, biases of article selection may arise from the author's previous training and working experiences in this field. Having been a practitioner in NPD management, the author may unconsciously try to maintain and even protect his own "theory of action" (Argyris, 1991). The author has been aware of the above problems and has consciously attempted to overcome the possible biases mentioned. The literature review, to a large extent, can be assumed to be non-biased and comprehensive enough to cover most of the key issues relevant to the current study.

The Issues and Debates

The current review has categorised the vast amount of literature into three broad streams of thought, i.e., the Determinants School, the Systematic School, and the Design School. The Systematic School studies were further classified into several detailed research approaches, i.e., Generic Recipe Studies, Communication Pattern Studies, Interface Studies, Japanese Practices, Organisational Learning Studies, and Project Management Techniques and Information Systems. These various of research approaches embraced distinct research assumptions or driving forces that led to their particular theoretical perspectives. Table 2.6 is a summary of these research approaches as discussed earlier in this chapter.

Determinants School studies hypothesise a direct linkage between environmental situations/conditions and NPD performance. To reveal the dynamic nature of these environmental situations/conditions, these studies have provided the most comprehensive investigation of contingent factors in NPD management. However, the omission of actual NPD managerial efforts in the models largely reduces the applicability of research results from this stream of studies. The Systematic School studies have shown actual managerial practices during innovation process

Table 2.6 Contributions and Drawbacks: Summary of Previous NPD Studies

School of Thought	Studies	Key Authors	Key Driving Forces	Key Dependent Variables	Key Independent Variables	Major Conclusions	Major Contributions	Major Drawbacks
Determinants School	Determinants Studies (Section 2.4)	R.G. Cooper E.J. Kleinschmidt X.M. Song	Statistical Forecast	NPD performance	environmental contingencies; nature of products or projects	NPD performance was given according to its contingency situations	a complete and structural discussion of NPD contingency factors	ignored the actual managerial efforts during NPD
Systemic School	General Guideline Studies (Section 2.5.1)	J.B. Quinn R. Rothwell T. Peters	General Management Theories	NPD performance	general management practices	NPD management was an extension of general management theories	a handful of general guidelines for managing NPD	NPD may require specific managerial arrangements other than the general management theories
	Communication Pattern Studies (Section 2.5.2)	T.J. Allen S.R. Epton R. Katz	Social Network Theories	NPD performance	intra-lab communication patterns	identified the "gatekeeper" role; the higher quality the communication within the lab, the better the NPD (project) performance	constructed an information processing based NPD management framework	ignored the interaction between R&D and its outside world
	Interface Studies (Section 2.5.3)	W.E. Souder A.K. Gupta D.L. Wilemon	Organisational Behaviour Theories	NPD performance	patterns of inter-functional interactions	NPD performance was largely determined by the quality of inter-functional integrations	highlighted the importance of organisational climate that influences NPD performance	did not recognize the key nature of NPD that is knowledge creating but not just conflict resolution
	Japanese Practices (Section 2.5.4)	M. Aoki I. Nonaka K.B. Clark	The rising of Japanese economic power	NPD performance	Japanese NPD management practices	Japanese NPD management practices were unique and especially suitable for product innovation management	constructed an knowledge based NPD management framework	lack of theoretical support; perhaps culture barriers exist that prevent the immigration of managerial know-how
	Organisational Learning Studies (Section 2.5.5)	D.Leonard-Barton K. Pavitt D. McKee	Organisational Learning Theories	NPD performance	mechanisms that *facilitate* organisational learning	only learning organisations can promote and sustain a long lasting innovativeness	constructed an knowledge based NPD management framework	*theories far too abstract* and lacking in practical guidelines for real-world implementation
	Project Management Techniques and Information Systems (Section 2.5.6)	R. Cordero V.A. Mabert M.R. Millson	The rapid technological progress of mathematics and computer sciences	NPD performance	project management techniques and information systems	project management techniques and information systems were useful in managing NPD projects	provided better tools for managing NPD projects	mainly focused on the refinement of technical tools and less to do with the development of management theories
Design School	Contingency Studies (Section 2.6)	N. Karagozoglu W.B. Brown R.T. Keller	Contingency Theory	Actual Managerial Practices	environmental contingencies; nature of products or projects	NPD performance was eventually decided by the level of fit between managerial systems and its incumbent contingency factors	drew insight from organisational contingency theories and threw light to a new approach of NPD management studies	still in its budding stage; lack of strong empirical support; within NPD context, still lack of theoretical conceptual structures

Source: the current study

are the key issue in NPD. In addition, Contingency studies also asserted that contingent factors essentially affect managerial activities. Contingent factors alone never decide NPD performance. It is the "fit" between contingent situations and the incumbent managerial efforts that matters.

Systematic School researchers have been the major contributors to our understanding of the managerial practices during NPD. Generic Recipe studies have successfully extended the concepts as well as the applications from general management theories to the product innovation arena and provided broad and well-structured guidelines for effectively managing NPD. Communication Pattern studies pointed out the nature of product innovation as a social network system where information acquisition and transmission are the basic phenomena of NPD. Interface studies highlighted the needs of integration among different functional areas and solidified the concept of inter-functional information processing as the focal issue of NPD management. Many project management techniques and information systems therefore were developed to improve the efficiency of NPD information accumulation and processing. Finally, to some extent, such an information processing view of NPD reality was later replaced with the emerging concept of knowledge creating and digesting as proposed by Japanese practices and Organisational learning studies.

Although the Systematic School of thought has provided useful theoretical models for managing NPD activities, their "internal" focus on these managerial "activities" meant the interaction between the project's internal and external environment has been neglected. As suggested by the Contingency scholars, any social system (like a NPD system) should be an open one where contingent factors play the key role in determining the actors' behaviour within the system. The Determinants School studies also asserted that these contingent factors eventually moderated NPD results. The Systematic School of thought hence was questioned, because these studies failed to reflect the nature of the entire NPD system.

The Design School studies promoted a contingent view of NPD reality, which combined both Systematic and Determinants streams of thinking. They inherited the open system approach of organisation theories and further extended these theories to the application of product innovation management. Their focus on the interaction between contingent factors and

NPD managerial practices has thrown light on a new direction of NPD theory development. However, as this stream of work is still in its infancy, there is a lack of in-depth contingency studies into NPD management. Both the contingent variables suggested by the Determinants School of thought and the managerial efforts discussed by the Systematic School researchers have not been sufficiently analysed in NPD contingency studies. This provides opportunities for the current study.

An Integrated View of NPD Reality

As suggested by previous researchers, the core of NPD can be seen as a system for information processing and knowledge creation and assimilation. The focus of NPD management on information and knowledge-related issues does not dismiss the importance of general management theory that was recommended by the Generic Recipe studies. In effect, there are close associations between the wisdom of general management theories and the effective management of information flow and knowledge accumulation. The emphasis on information processing and knowledge management is a reflection of the truth that they underpin effective management and execution of NPD activities as stated by the Communication Pattern studies, the Interface studies, the Japanese studies, and the Organisational Learning studies.

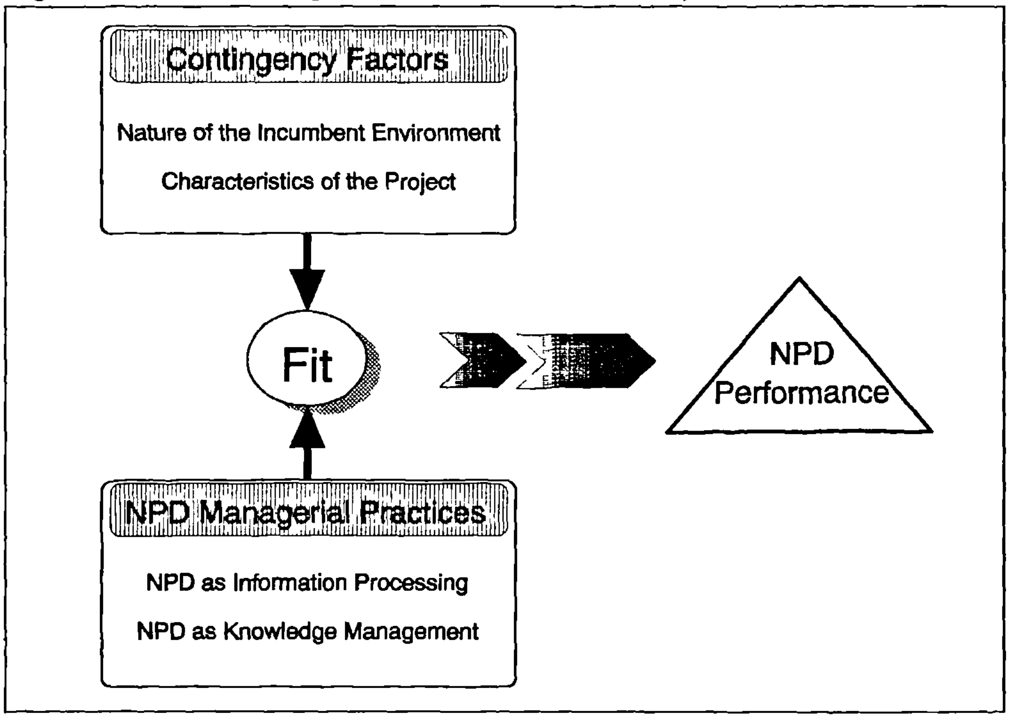
However, such an information processing view of NPD is not limited solely to R&D laboratory management as described by the Communication Pattern studies. Its role is also not restricted to resolving multi-functional conflicts as proposed by the Interface stream of work. The effective implementation of such an information processing mechanism also cannot be explained fully by using abstract concepts such as "organic" or "mechanistic" organisational structures or "formal" or "informal" communication patterns as highlighted by most Design School researchers. In effect, it is an open system for product innovation practices that takes care of the highly complex organisational dynamics within and amongst a variety of functional areas as well as the interaction between the organisation and its outside world. It is the effectiveness of these interactions, which determine NPD performance, in addition to managerial efforts, and certainly not managerial efforts alone.

As presented in Figure 2.9, the "fit" between NPD managerial effort and its incumbent contingent factors decides the results of product innovations. The core of NPD management, as mentioned above, is regarded as information processing and knowledge creating/digesting. On the other hand, in summarising the conclusions from the Determinants School and the Design School studies, contingent factors can be broadly classified into two basic forms, i.e., the characteristics of the project and the incumbent environment for developing this project. The environmental influences here referred to both the external and the internal environment. This means that this integrated view of NPD management accepts the dynamics of the market and technology external to the firm, as well as the skills or competencies, manpower, and available resources within the firm as the key contingent factors that shape NPD activities.

A Necessity of Integrated Model

The comprehensive literature review allows the researcher to obtain a bird's eye view of product innovation management. The three broad schools of thought identified by the current study all have made important contribution to the development of NPD management theories.

Figure 2.9 An Integrated View of NPD Reality



Source: the current study

However, as researchers tend to concentrate on their particular research interests, each approach encounters, to a greater or lesser degree, additional constraints imposed by time, methodology, selection of research variables or access to information. The current study asserts that a more integrated model is needed to bridge apparent gaps left by previous product innovation studies. Such a model should consider a contingency approach to managing NPD, and focus more intently on information processing, knowledge creation, and assimilation. The next chapter deals with the above integrated view of NPD management. The conceptual framework as well as the research hypotheses of the current study will also be discussed.

Notes

1. A brief historical review of innovation studies during the 1950s to the 1980s can also be found in Rothwell, R. (1992), 'Successful Industrial Innovation: Critical Factors for the 1990s,' *R&D Management*, 22, 3, 221-39. Rothwell differentiated the studies of innovation into 5 distinct creative processes, i.e., technology push, need-pull, coupling model, integrated model, and systems integration and networking model. He asserted that such evolution of innovation process resulted from the historical shift of corporate strategic foci. Each generation of process had its own strategic purposes and was simply a reflection of its contemporaneous human society and historical events. His view was sharp and deep enough to lead our thinking into the future of innovation management. However, the literature review in this article was rather limited and unstructured and most of the inductions were based merely on his own observations. The current study inherits his evolutionary view of innovation theory development and further extends this perspective to a more complete and integrated system.

2. Allen and George (1989) provided a bibliographic study of innovation management based on articles which appeared in *R&D Management* since 1970. They identified 17 major research areas in studying R&D management and distinguished the shift of research interests between 1970-1975, 1975-1981, and 1982-1987. (See: Allen, T.J. and V. George (1989), 'Changes in the field of R&D Management Over the Past 20 Years,' *R&D Management*, 19, 2, 103-13). The current study does not fully accept their view of innovation theory development and their proposed typology of innovation studies. First of all, their bibliographic review of literature was limited only to the journal of *R&D Management*. It was extremely lacking in its representativeness of the whole body of innovation studies. Secondly, their categorisation did not actually reflect the nature of these previous studies. For example, the interface studies of R&D which never appeared in their list of research topics can easily be found in *R&D Management* since the 1970s (e.g., Olin, 1973; Bergen, 1982; Bergen and Miyajima, 1986; Bonnet, 1986). Thirdly, their classification of research topics was unstructured and makes it difficult to provide useful insight for further researches.

3. The early idea for constructing this framework was first developed by the author for an internal presentation at the University of Warwick, England, on 27th January 1993 and later appeared (co-authored with Dr. Veronica Wong) at the 22nd EMA Conference (Chou, T.J. and V. Wong (1993), 'How Corporate Information Requirements/Transmission Patterns Vary According to New Product Type: An Empirical Study,' Working paper presented at *the 22nd EMA Conference*, ESADE, Barcelona, Spain, May, 1587-9). In this early classification NPD studies were categorised into three broad streams of thought, i.e., the Communication Pattern School, the Determinants School, and the Interface School. However, owing to the deficiency of this early work it was difficult to cover such a great amount and variety of NPD literature. This framework was further refined and extended in an attempt to describe more fully previous research approaches. Meanwhile, considerable effort has been focused on building a computerised literature database of product innovation studies. With the help of computerised automatic indexing and contextual referencing, the current study is therefore able to introduce a more comprehensive view of NPD studies.

4. Network Analysis was a stream of research methodology originally developed by the social theorists in an attempt to analyse the interaction of organisational conditions and human activities. The underlying assumption of this approach was based on the concept that organisation is a social assembly of individuals presenting a relatively stable pattern of interactions. Tichy et al. (1979) suggested that this research approach can be traced back to as early as the 1920s and originated from at least three broad schools of thought, i.e., (1) Sociology, (2) Anthropology, and (3) Role Theory. However, these early studies were mostly interested in investigating social community and organisational behaviour. T.J. Allen perhaps was the first to employ the network approach in researching innovation activities. Most of his work was done

by questionnaire surveys that asked respondents to state the persons involved and the topics of actual technical communications that were discussed on the day before the research date and continue to repeat the inquiry over a certain period. The frequencies of communications were thus calculated and the resultant data were therefore pulled into an individual-by-individual matrix for further investigation. Ritchie (1977) has developed a clear mathematical procedure for dealing with such data sets. Stein (1992) has provided a comprehensive description about the whole process of implementing network approach. For more information on the Network Analysis approach please refer to the following articles: Tichy, N.M., M.L. Tushman, and C. Fombrun (1979), 'Social Network Analysis for Organizations,' *Academy of Management Review*, 4, 4, 507-19. Ritchie, E. (1977), 'Communication Networks: Tools for the Efficient Management of R&D,' *R&D Management*, 7, 2, 85-8. Stein, E.W. (1992), 'A Method to Identify Candidates for Knowledge Acquisition,' *Journal of Management Information Systems*, 9, 2, Fall, 161-78.

5. Organisational Learning Theory can be traced back to as early as the 1930s when U.S. Air Force Production workshops started to examine the relationships between product output and productivity (Wright, 1936). The earliest form of organisational learning concept showed that the greater the cumulated output (i.e., learning by doing), the higher the productivity gains (i.e., the direct labour hours required to complete tasks decreased). Later theorists extended this notion and asserted that it can also be applied to more functional areas than manufacturing. For example, innovation can be regarded as a process of learning where knowledge accumulation is a function of experience (or learning by doing) and therefore determines the effectiveness and efficiency of innovation (e.g., David, 1975; Teece, 1986; Cohen and Levinthal, 1989; Pavitt, 1990; Malerba, 1992; McKee, 1992). Four streams of thought concerning individual learning have been regarded as contributing to the construction and development of Organisational Learning Theory. They were: (1) Conditioning Theory (e.g., Skinner, 1938), (2) Verbal Learning or Interference Theory (e.g., Postman, 1963), (3) Critical System Theory (e.g., Piaget and Inhelder, 1969), and (4) Information Processing Theory (e.g., Greeno, 1980). Shrivastava (1983) provided a typology of organisational learning systems that categorizes the relevant theories into four basic concepts, i.e., (1) organisational learning as adaptation; (2) organisational learning as assumption sharing; (3) organisational learning as developing knowledge of action-outcome relationships; and (4) organisational learning as institutionalized experience. For more in-depth descriptions of Organisational Learning Theory, the following articles are very useful and interesting: Argyris, C. (1977), 'Double Loop Learning in Organization,' *Harvard Business Review*, September-October, 115-25. TShrivastava, P. (1983), 'A Typology of Organisational Learning Systems,' *Journal of Management Studies*, 20, 1, 7-28. Walsh, J.P. and G.R. Ungson (1991), 'Organizational Memory,' *Academy of Management Review*, 16, 1, 57-91. Malerba, F. (1992), 'Learning by Firms and Incremental Technical Change,' *The Economic Journal*, 102, July, 845-59. Dooley, J. (1993), 'Piaget, Self-Organizing Knowledge, and Critical Systems Practice,' *Systems Practices*, 6, 4, 359-81.

6. Contingency Theory was a stream of thought emerging from the late 1950s and prospering in the 1970s, asserting that organisational structures and leadership styles must be contingent upon various environmental situations (Woodward, 1958; Burns and Stalker, 1961; Lawrence and Lorsch, 1969; Kast and Rosenzweig, 1973; Aldrich, 1979). This stream of work was mainly a reflection of the increasingly dynamic marketplace that resulted from accelerating technological progress after World War II. As firms gradually perceived the pressure of higher interaction with their outside world, the organisational management theories traditionally based on a closed system concept cannot help but break down. Many scholars started to stress an open system view of organisation that argued firms must adapt themselves according to particular contingent situations. Kast and Rosenzweig (1973: 313) defined the contingency approach of organisation management as one that: "... seeks to understand the interrelationships within and among subsystems as well as between the organisation and its environment and to define patterns of relationships or configurations of variables. It emphasizes the multivariate nature of organisations and attempts to understand how organisations operate under varying conditions and in specific circumstances. Contingency views are ultimately directed toward suggesting organisational designs and managerial actions most appropriate for specific situations." In recognizing the nature of organisation as information processing, subsequent writers also designed the concept of information systems in discussing contingency theory (e.g., Daft and Weick, 1984; Daft and Lengel, 1986; Iivari, 1992; Keller, 1994). They highlighted the role of "fit" between organisational design (i.e., information processing systems) and its incumbent contingent situations as the major issue in organisational theory development. This stream of work further became the core of the Information Processing School in organisational studies.

Chapter Three 3

Research Questions, Hypotheses, and Conceptual Framework

The last chapter concludes that a more integrated view of NPD management is necessary, to appreciate the reality of NPD management. Principally, this view suggests that a major thrust in NPD is the management of information processing and knowledge accumulation. Additionally, the "fit" between NPD managerial efforts and the incumbent environment decides the outcome of product innovation. Although this assertion is based on a comprehensive review of the literature on product innovation, previous academic efforts have focused little on the notion of contingency management of NPD information. This chapter proposes a contingency model of product innovation centred on the management of information processing and knowledge accumulation. Several propositions are developed which are subsequently tested in this study.

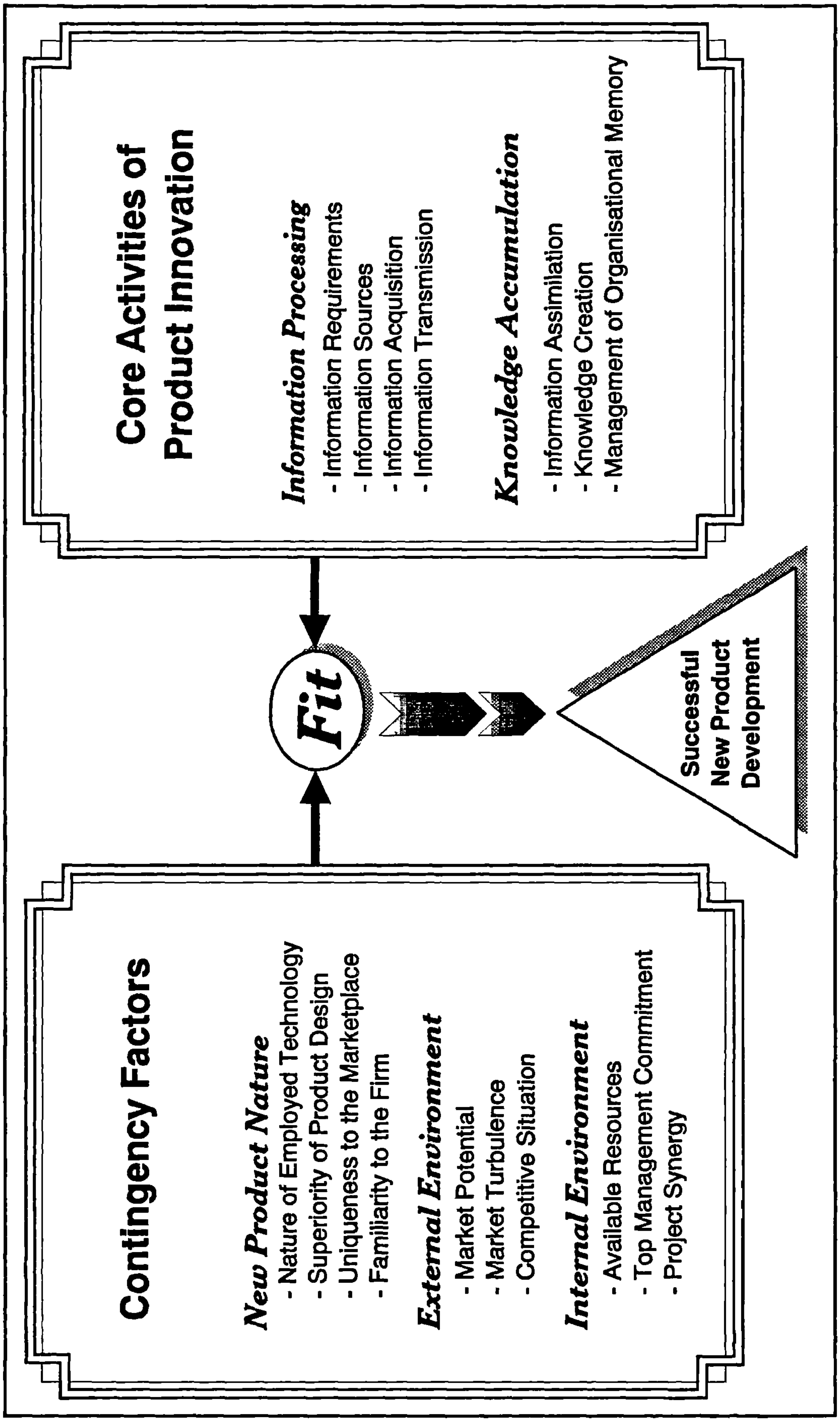
3 Research Questions, Hypotheses, and Conceptual Framework

§3.1 Introduction

Chapter Two offers an integrated perspective on NPD. Successful new product development is achieved by means of proficient management of the "fit" between information processing/knowledge accumulation and its incumbent external and internal environment. Such an assertion is highly relevant to the key ideas of the scholars of Organisational Information Processing (e.g., Daft and Weick, 1984; Daft and Lengel, 1986; Keller, 1994). They suggested that, for any organisation, the content, amount, quality, and timing of information acquisition are contingent upon specific environmental situations/conditions. According to this view, new product developers should formulate information processing mechanisms based on specific NPD contingency situations, so as to insure successful project implementation.

This chapter proposes an information processing and knowledge accumulation model of NPD management based on a contingency approach. Figure 3.1 presents the basic concepts. The focal interest is, how successful NPD projects manage information processing and knowledge accumulation, by adapting to specific projects. NPD information processing and knowledge accumulation are discussed in Section 3.2. This includes topics concerning information requirements, information sources, information acquisition, transmission, and assimilation, knowledge creation, and the mechanisms of organisational memory management. A brief review of contingent factors that influence the above information/knowledge management activities, as well as the concept of "fit" for product innovation situations is presented in Section 3.3. Based on these discussions, Section 3.4 suggests a contingency model of product innovation management, centred on information processing and knowledge accumulation. Finally, Section 3.5 summarises the current research hypotheses investigated in the current study.

Figure 3.1 Conceptual Framework of the Current Study



§3.2 Information Processing and Knowledge Accumulation as an Organising Paradigm

Many scholars have asserted that information processing and knowledge accumulation are the basic activities of product innovation management. Such assertions can be traced back to as early as the 1960s when writers started to investigate the social networks of scientists and engineers in large research laboratories. They stated that the management of information acquisition and communication, in essence, are the core tasks of innovation management (e.g., Hagstrom, 1965; Allen, 1966b; Rosenbloom and Wolek, 1967; Gertsberger and Allen, 1968; Allen and Cohen, 1969). Subsequent researchers also highlighted the importance of information processing in NPD management (e.g., Allen, 1970; Rothwell et al., 1974; Rubinstein et al., 1976; Cooper, 1979; Souder and Chakrabarti, 1979; Epton, 1981; Maidique and Zirger, 1984; Baker et al., 1986; Hauptman, 1986; Cooper and Kleinschmidt, 1987a; Rothwell, 1992; Cooper et al., 1994; Parry and Song, 1994). Robinson and Fornell (1985) in addition reported that a great amount of new product pioneers' advantage can eventually be attributed to their access to information and acquisition of earlier information than their slower counterparts. Other scholars also suggested mechanisms for fostering information transmission within and between functional departments (e.g., Hall and Ritchie, 1975; Taylor and Utterback, 1975; Pruthi and Nagpaul, 1978; Shanklin and Ryans, Jr., 1984; Bonnet, 1986; van de Ven, 1986; Souder, 1987; Gupta and Wilemon, 1988; Grady and Fincham, 1990; Pinto and Pinto, 1990; Griffin and Hauser, 1992; Johne, 1992; Song and Parry, 1993; Moenaert et al., 1994).

On the other hand, the "Japanese Practices" and the "Organisational Learning" studies highlighted deficiencies in the information processing view of innovation management. These studies suggested that knowledge creation and accumulation (i.e., organisation learning and organisational memory management) more appropriately describe NPD management activities (e.g., Nonaka and Johansson, 1985; Takeuchi and Nonaka, 1986; Ealey and Soderberg, 1990; Pavitt, 1990; Nonaka, 1990, 1991; Ghoshal and Butler, 1992; McKee, 1992). Still others proposed a variety of managerial arrangement which would improve the quality and effectiveness of the new products learning process (e.g., Goldberg et al., 1981; Aoki, 1986, 1988, 1990; Meyers and Wilemon, 1989; Clark and Fujimoto, 1990; Ealey and Soderberg, 1990; Nonaka, 1990, 1991; Kodama, 1992; Leonard-Barton, 1992ab; McKee, 1992; de Meyer, 1993; Henderson, 1994). However, the creation and accumulation of knowledge cannot exist without high quality information processing. To reveal the mechanisms of organisational memory and learning, one should first understand the nature of information, and its relationship with data and knowledge.

Information Processing Model

Wildavsky (1983) suggested that the structure of organisation is designed to reduce data to a manageable form. He wrote, "... organizations exist to suppress data (p.29)." By this, he meant that organisations are information processing machines that transfer raw data into purposeful information. Thus, information can be seen as data that have been organized or structuralised and therefore endowed with meaning (Wildavsky, 1983; Drucker, 1988; Glazer, 1991). The conversion of data to information requires rational conceptualisation efforts. Rules for organising data should be constructed so as to filter the great amount of data rationally and efficiently (Wildavsky, 1983). The originally rich and organic form of data is then transferred into a form that is systematic and mechanistic. The resultant information therefore is formal and quantifiable.

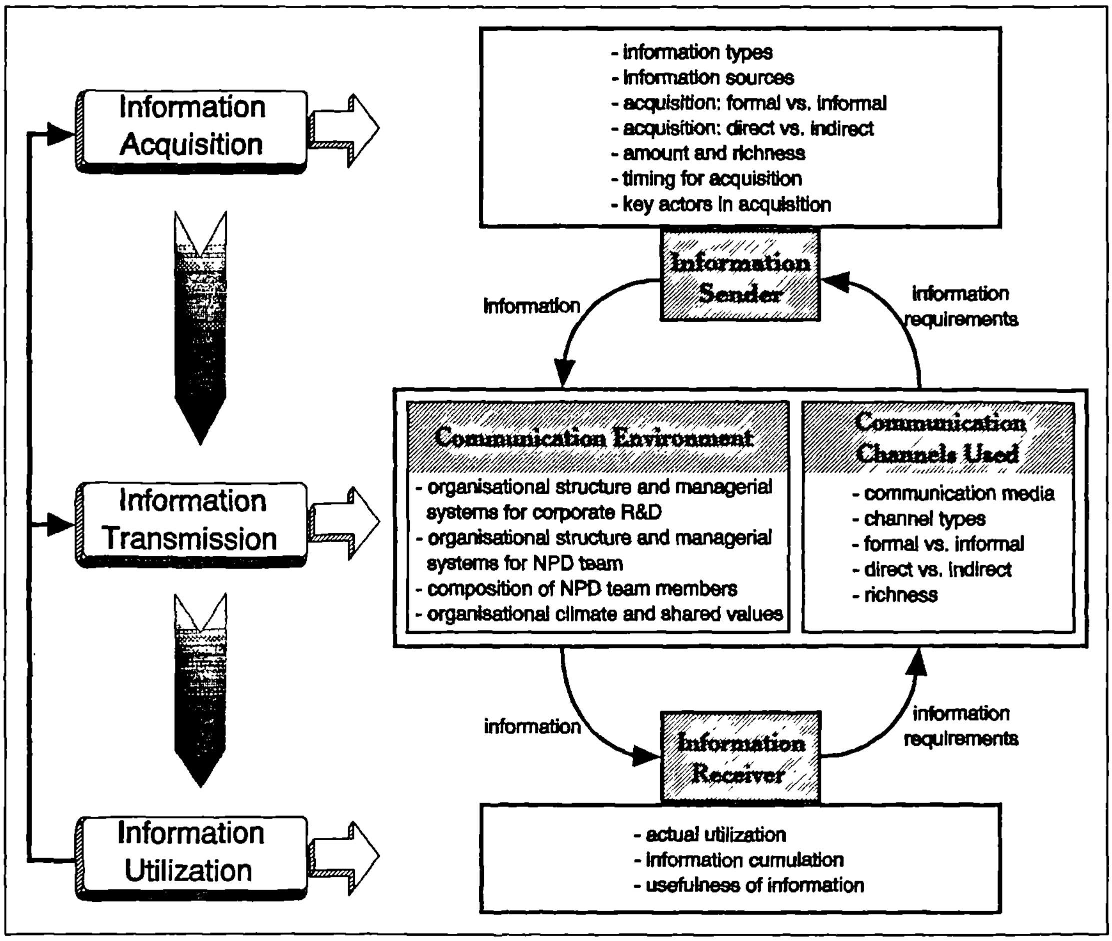
Moenaert and Souder (1990) and Souder and Moenaert (1992) are perhaps among the first writers to provide complete information processing frameworks for R&D activities. They highlighted that proficiency of organisational information processing was the only reason for successful innovation outcomes. The value of information processing, according to their assertion, was to eliminate the uncertainties raised from both technological progresses and marketplace dynamics during innovation. They suggested that a better integration mechanism (i.e., "out-of-role behaviours") between marketing and R&D would be the key to improve information processing. In addition, they argued that such an integration mechanism was determined by other structural factors such as task specification, self-containment of project structure, interfunctional climate, and interfunctional manpower flow. However, the focus of their model was determinants that influence R&D information processing activities rather than information processing itself. Furthermore, this model has yet to be empirically examined.

More (1978) in illuminating Kernan (1971)'s concept of the "information handling process" provided a three-stage model for explaining information processing-related activities, i.e., ***information acquisition, information processing***, and ***information utilisation***. They regarded information handling as a process of acquiring external information for internal exploitation. Kimbrough and Moore (1992) further distinguished the basic components of communication from information processing. They suggested that any information processing, at least, contains elements such as sources, sender, receiver, and destination. Along with the ***information requirements*** from the ***user*** (destination), the ***information sender*** acquires information from the ***sources*** and therefore transmits them through ***communication channels*** to the ***information receiver***, who further passes this information to the user.

Moorman (1995) went even further to investigate cultural antecedents (i.e., ***communication environment***) that influence organisational information processing, which in turn determines NPD performance. He defined four key processes of organisational information processing, i.e., (1) information acquisition, (2) information transmission, (3) conceptual utilisation (i.e., indirect use of information), and (4) instrumental utilisation (i.e., direct use of information). Using a two-dimensional model of cultural antecedent (i.e., internal/external orientation, and informal/formal governance), he asserted that the processing of organisational information is moderated by such cultural values. His empirical results suggested that the high-performers tend to put a cultural value on internal orientation and informal governance (i.e., Clan Culture), which encourages information transmission and conceptual as well as instrumental utilisation.

Figure 3.2 shows a framework describing the process of NPD information processing. This process commences from a need for information acquisition triggered by the information user (normally the information receiver). He passes the message of specific information requirements to the information acquisitor (normally the information sender) via organisational communication channels. Based on the requirements of the user, the information sender identifies suitable information sources and defines the quantity, quality, and timing for such an information acquisition. Finally this acquired information is represented in certain forms of communication media and later transmitted to the receiver through organisational communication channels for further exploitation. During the whole process, the communication environment plays a vital role in deciding the quality of information transmission. This includes the

Figure 3.2 Organisational Information Processing Model for Product Innovation



Source: the current study

organisational structure (e.g., Jermakowicz, 1978; Quinn, 1985; Ansoff, 1987) and managerial systems (e.g., Ansoff and Stewart, 1967; van der Meer and Calori, 1989; Grady and Fincham, 1990; Saleh and Wang, 1993) for single NPD project activities as well as corporate R&D systems as a whole. The composition of NPD team members (e.g., Bertodo, 1988; Peters, 1990; Kumpe and Bolwijn, 1994) and the organisational climate and shared values (e.g., Souder and Chakrabarti, 1979; Moenaert and Souder, 1990; Souder and Moenaert, 1992; Capon et al., 1992) are also key moderators in the process.

Information Requirements and Information Sources

As mentioned earlier, the identification of information requirements is the beginning of R&D information processing activities. Many researchers have discussed the timing/situation for exploiting internal, external, or personal information sources (e.g., Johnston and Gibbons, 1975; Goldhar et al., 1976; Dewhirst et al., 1978; Fischer, 1979; Rochford, 1991; Hauschildt, 1992), or in utilising secondary or primary sources (e.g., More, 1978). Other scholars suggested certain types of information that are important to product innovation. Table 3.1 shows a list of possible sources for NPD information acquisition. Table 3.2 is a summary of these information requirements.

Technology-related information is indeed the essential driving force that makes product innovation possible (e.g., Johnson and Jones, 1957; Holland, 1972; Goldhar et al., 1976; Fischer, 1979; Rogers, 1982; Batson, 1987; Carlsson, 1991). This information includes the observation and scanning of technological progress in product technology, manufacturing technology, and new parts, materials, and systems, as well as the identification of technical ideas, problems, and solutions. Except for in-house technological research and development, external information sources were also highlighted as important for strengthening NPD capability. Researchers suggested that linkages to universities and research institutes were also vital sources of acquiring technology-related information (Wigand and Frankwick, 1989; Gemünden et al., 1992; Chang

Table 3.1 Information Sources for New Product Development

Type of Sources	*Information Sources*
External	public databank literature/reports customers suppliers competitors consultants university, research institutes government agencies distributors partners of cooperation, affiliated companies fairs, shows, exhibits
Internal	in-house R&D activities in-house research, survey internal documents, literature internal databank, information systems
Personal	knowledge, judgement, or experiences from CEO/top management knowledge, judgement, or experiences from NPD team members knowledge, judgement, or experiences from other colleagues

Sources: based on Johnston and Gibbons (1975); Goldhar et al. (1976); More (1978); Fischer (1979); Mansfield (1981); Nilakanta and Scamell (1990); Ashton et al. (1991); Rochford (1991); Gemünden et al. (1992); Hauschildt (1992) and organised by the current study.

Table 3.2 Information Requirements in Product Innovation

Information Requirements	Description
1. *Goal/Strategy Related Information* Sugden (1973); Phelps (1977); Dewhirst et al. (1978); Brown and Karagozoglu (1989); Dougherty (1990); van Dierdonck (1990); Carlsson (1991); Parnaby (1991)	- corporate competitive strategy - product positioning and strategy - expectation of new product performance - project schedule and cost
2. *Market Related Information* Johnson and Jones (1957); Sugden (1973); Goldhar et al. (1976); Cooper (1979, 1981); More (1984); Gupta et al. (1985); Calantone and di Benedetto (1990); Dougherty (1990); Ashton et al. (1991); Song and Parry (1992)	- market trends - market size - market potential - market feasibility assessment - test market results
3. *Regulation, Law, and Industrial Standard* Gupta et al. (1985); Ashton et al. (1991)	- government regulations, laws - subsidy - Industrial standard - patent related information
4. *Supplier, Component Related Information* Burt and Soukup (1985); Dougherty (1990)	- list of possible suppliers - availability of necessary components, materials and systems
5. *Competitor Related Information* Cooper (1979, 1981); Gupta et al. (1985); Bonnet (1986); Batson (1987); Dougherty (1990); Carlson (1991); Song and Parry (1992)	- number of competitors - competitors' strategies - competitors' capabilities in new product design, manufacturing, and marketing
6. *Customer Related Information* Tauber (1960); Cooper (1979, 1981, 1988); Parkinson (1981); Rogers (1982); More (1984); Gupta et al. (1985); Bonnet (1986); Batson (1987); Szakonyi (1988); Calantone and di Benedetto (1990); Dougherty (1990); Carlsson (1991); Gemünden et al. (1992); Song and Parry (1992)	- customers' needs, wants, and preferences - customers' future needs - customer buying behaviour - consumer responses to existing products
7. *Cost/Price Related Information* Cooper (1979, 1981); Burt and Soukup (1985); Calantone and di Benedetto (1990); Dougherty (1990); Parnaby (1991)	- customer price sensitivity - development cost - manufacturing cost - pricing decision
8. *Product Related Information* Phelps (1977); Cooper (1979, 1981); Parkinson (1981); Rogers (1982); Gupta et al. (1985); Bonnet (1986); Calantone and di Benedetto (1990); Dougherty (1990); Carlsson (1991); Parnaby (1991)	- re-engineering of competitors' products - product concept - product configuration
9. *Technology, Science Related Information* Johnson and Jones (1957); Holland (1972); Sugden (1973); Johnston and Gibbons (1975); Goldhar et al. (1976); Dewhirst et al. (1978); Fischer (1979); Cooper (1979, 1981); Rogers (1982); Myers (1983); Bonnet (1986); Batson (1987); Calantone and di Benedetto (1990); Dougherty (1990); Sen and Rubenstein (1990); Ashton et al. (1991)	- observation of new technologies - technical feasibility assessment - technical ideas/problems/solutions - new technologies of components, materials, and systems
10. *Manufacturing Related Information* Cooper (1979, 1981); Bergen (1986); Calantone and di Benedetto (1990); Dougherty (1990); van Dierdoonck (1990); Carlsson (1991); Parnaby (1991)	- production feasibility - new manufacturing methods - manufacturing process and requirements

et al., 1993). Joint research with other non-competitive firms was also found useful in exploiting technological know-how from other industries (Aoki, 1986, 1988, 1990; Roberts and Mizouchi, 1989; Kodama, 1992; Gemünden et al., 1992; Samuels, 1994).

Customer-related information is also crucial in deciding the effectiveness of NPD. Szakonyi (1988) reported that firms often encountered difficulties in selecting proper development projects because they failed to define customers' needs (especially their future needs). Empirical evidence suggested that customer-related information was not only useful in defining suitable projects, but also crucial in guiding the rest of the NPD process (e.g., Cooper, 1979, 1981; Bonnet, 1986; Dougherty, 1990; Song and Parry, 1992). Scholars therefore suggested a close link with customers can greatly benefit product innovation (e.g., Parkinson, 1981; von Hippel, 1982; Gemünden et al., 1992; Peacock, 1993).

While customer-related information is more to do with the understanding of consumer characteristics, as well as their buying behaviour, ***market-related information*** takes into account the trends, size, and potential of the targeted markets. Many scholars have observed that the availability of market-related information strongly determined NPD performance (e.g., Sugden, 1973; Cooper, 1979, 1981; More, 1984; Calantone and di Benedetto, 1990; Ashton et al., 1991; Song and Parry, 1992). Some studies also highlighted the fact that quality of this type of information was in essence the key to new product success (Gupta and Wilemon, 1988, 1990; Moenaert et al., 1992; Song and Parry, 1993). Scholars therefore suggested a closer coordination and integration between the marketing and R&D to facilitate transmission and utilisation of market-related information (Shanklin and Ryans, Jr., 1984; Gupta et al., 1985; Bonnet, 1986; Souder, 1987, 1988; Pinto and Pinto, 1990; Carlsson, 1991; Song and Parry, 1992).

Previous research also stressed the importance of ***goal/strategy-related information*** (e.g., Phelps, 1977; Brown and Karagozoglu, 1989; Van Dierdonck, 1990; Parnaby, 1991) and competitor-related information (e.g., Cooper, 1979, 1981; Gupta et al., 1985; Dougherty, 1990) in product innovation. Goal/strategy-related information addresses issues concerning the position and role of a specific NPD in the corporation's overall competitive strategy. This is the key point of how NPD teams can develop and encourage the sharing of common values, beliefs, and morale. This is also the major concern of top management about how their entrepreneurial vision can be fulfilled through NPD. However, the value of goal/strategy-related information is based on good quality ***competitor-related information.*** Firms need to know about their competitors so as to figure out their competitive NPD strategies. They need to understand competitors' core capabilities and therefore anticipate competitors' responses to their offensive NPD efforts.

Product-related information and ***manufacturing-related information*** are also the key to successful NPD. For example, the assessment of product design feasibility, configuration, and mass production is found to be crucial in screening new product ideas (e.g., Cooper, 1979, 1981; Calantone and di Benedetto, 1990; Dougherty, 1990; Carlsson, 1991; Parnaby, 1991). Better interaction and information-sharing amongst the team throughout product concept development, prototyping, and process design are called for, so as to guarantee final product integrity (Clark and Fujimoto, 1990, 1991b). As a result, a great deal of effort is directed at utilizing computerised techniques and information systems (e.g., CIM, CAD, CAM) to provide better linkages between product concept and manufacturing (Cordero, 1991; Mabert et al., 1992; Millson et al., 1992; Fjermestad and Chakrabarti, 1993).

Other information types such as ***cost/price-related information*** (e.g., Cooper, 1979, 1981; Burt and Soukup, 1985; Dougherty, 1990; Parnaby, 1991), ***supplier/component-related information*** (e.g., Burt and Soukup, 1985; Ashton et al., 1991), and ***regulation, laws, and industrial standard*** (e.g., Gupta et al., 1985; Ashton et al., 1991) have also been shown to have an impact on NPD success. However, these information types were less stressed in previous studies.

Information Transmission Channels

Previous researches have identified a variety of channels or media frequently used for NPD information transmission (e.g., Goldhar et al., 1976; Shanklin and Ryans, Jr, 1984; Souder, 1987). These information channels were usually categorised by scholars into typologies so as to ease their construction of theories or models. The most frequently cited typologies that describe the nature of communication channels are the ***highly rich*** versus ***less rich*** comparisons, the ***informal*** versus ***formal*** perspectives, and the ***direct*** versus ***indirect*** modes (see Table 3.3). Face-to-face inter-personal interactions, contacts, dialogues, and discussions were often referred to as highly rich (Holland et al., 1976; de Meyer, 1993), informal (Fischer, 1979; Nagpaul and Pruthi, 1979; Rogers, 1982: 115-6; Bart, 1993; Keller, 1994), and direct (Clark et al., 1987: 760; Clark and Fujimoto, 1990: 114-5, 1991a: 49-54; Adler et al., 1992: 28; Yeaple, 1992; Samuels, 1994: 26) communication approaches, while written documentation, reports, and journals were regarded as less rich (Holland et al., 1976; Saunders, 1981; Daft and Lengel, 1986) and very formal (Holland, 1972; Fischer, 1979; Nagpaul and Pruthi, 1979; Rogers, 1982: 115-6; Ghoshal and Butler, 1992: 184; Shenhar, 1993) channels. Other paths for information transmission such as meetings, conferences, information systems, and organisational management systems were also often cited as formal and less rich channels (Holland, 1972; Goldhar et al., 1976; Saunders, 1981; Daft and Lengel, 1986; Iivari, 1992; Bart, 1993).

Table 3.3 Typologies of NPD Communication Channels

Channel Types	*Dimensions*				
	Formal	**Less Rich**	**Informal**	**Highly Rich**	**Direct**
inter-personal interactions			Fischer (1979); Nagpaul and Pruthi (1979); Rogers (1982: 115-6); Bart (1993); Keller (1994)	de Meyer (1993)	Samuels (1994: 26); Clark and Fujimoto (1990: 114-5); Adler et al. (1992: 28)
informal face-to-face discussions			Holland (1972); Goldhar et al. (1976); Nagpaul and Pruthi (1979); Clark et al. (1987: 760); Bart (1993)	Holland et al. (1976)	Clark *et al.* (1987: 760); Yeaple (1992); Clark and Fujimoto (1990: 114-5, 1991a: 49-54)
personal social networks			Ostroff and Kozlowski (1992); Bart (1993)		
face-to-face meetings	Goldhar et al. (1976); Ghoshal and Butler (1992: 184); Shenhar (1993)				
conferences	Goldhar et al. (1976)				
information systems, databases	Holland (1972); Saunders (1981); Daft and Lengel (1986); Iivari (1992)	Saunders (1981); Daft and Lengel (1986)			
organisational management systems	Bart (1993)				
written memoranda	Goldhar et al. (1976); Ghoshal and Butler (1992: 184); Bart (1993)	Holland et al. (1976)			
reports, books, or other documentation	Holland (1972); Goldhar et al. (1976); Fischer (1979); Saunders (1981); Rogers (1982: 115-6); Daft and Lengel (1986); Bart (1993); Shenhar (1993)	Holland et al. (1976); Saunders (1981); Daft and Lengel (1986)			

It would appear that formal channels are less rich and more indirect modes of information transmission, while informal ones are rich and direct. Moreover, as media and communication technologies continue to advance, Table 3.3 can never provide a comprehensive list of communication channels. The nature of many newly developed communication tools such as E-mail systems, Electronic Conferencing, and Groupware are rarely discussed in management literature. These emerging technologies, incorporating the power of computers, networking, and multimedia presentation, provide both formal and informal forms of information transmission, simultaneously.

Knowledge Accumulation and Organisational Memory Management

While information is meaningful and purposeful data, knowledge can be defined as useful information that has been properly digested and therefore can be exploited to guide behaviour or decision-making (John and Martin, 1984). The key mechanism that turns information into knowledge is the process of information assimilation. This is a process of learning for individuals and internalisation for the organisation. Unlike information which is mostly explicit, structured and almost represented in a rational way, knowledge may be tacit, intuitive, and often very subjective (Nonaka, 1991). Knowledge cannot be easily quantified or measured. It is a state of "theory of action" deeply ingrained within the individual's or organisation's value, belief, and skills (Argyris, 1977, 1986, 1991).

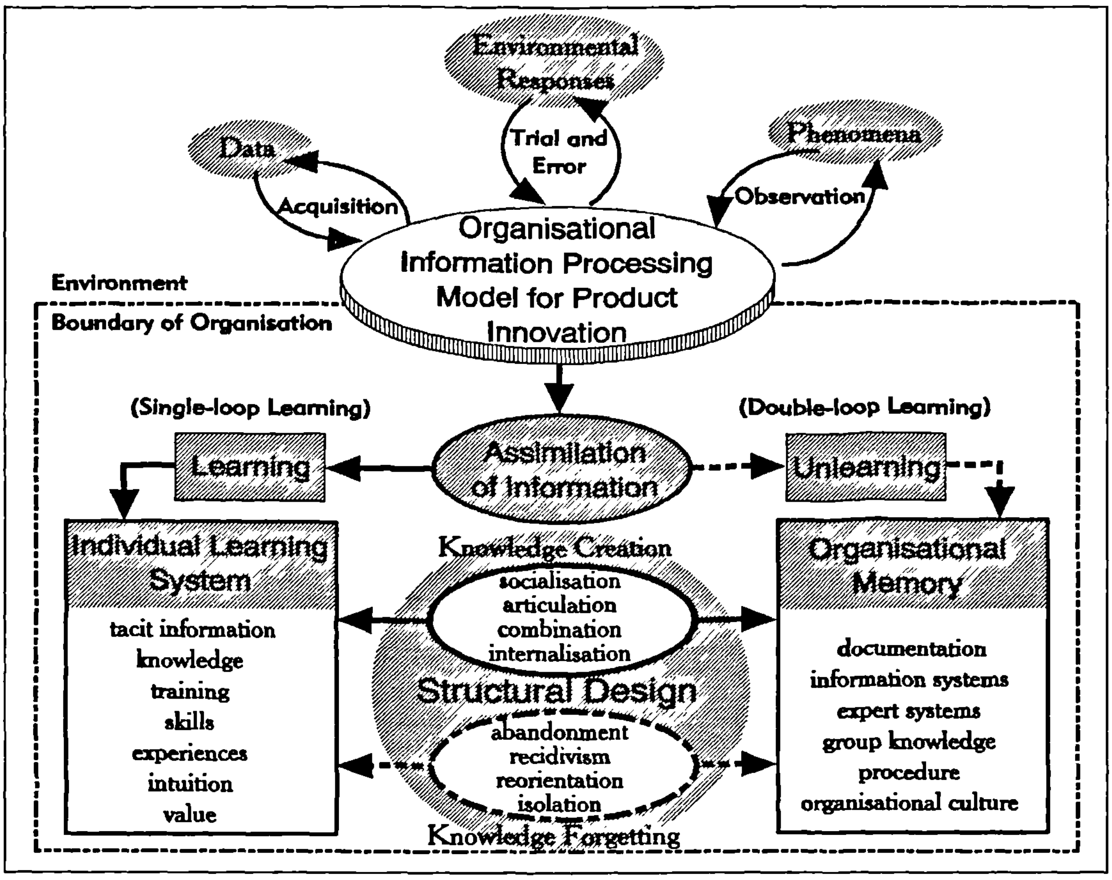
Knowledge also can be accumulated in time (Kandel et al., 1991). In an empirical study Gambardella (1992) showed that a higher degree of in-house technology accumulation improved the ability of firms to absorb and assimilate external knowledge. Therefore, it is worthwhile for firms to develop better skills in managing knowledge creation.

Nonaka (1991) suggested a framework for better knowledge management in product innovation. He observed that knowledge can be distinguished as having two basic forms, i.e., (1) tacit knowledge, which is difficult to be expressed either in oral communication or written documents, and (2) explicit knowledge, which can easily be understood and diffused through tangible media. He stated that the cumulated knowledge within the firm is eventually a result of information acquisition and assimilation company-wide where all members in the organisation take part in the process. The knowledge-creation mechanism begins with the "socialisation" process that extends individual-level tacit knowledge to organisation-level tacit knowledge. The "articulation" and "combination" processes help to transfer organisational tacit knowledge into explicit knowledge and further improve its usability in NPD. Finally, the "internalisation" process diffuses the organisational explicit knowledge to its members in an attempt to strengthen the skills and capability of all employees. (For more insight into the Nonaka Model, please see the discussion accompanying Figure 2.7 in Chapter Two).

Leonard-Barton (1992a) further defined the organisational "knowledge set" or "core capabilities" as embodying four basic dimensions, (1) employee skills, (2) technical systems, (3) managerial systems, and (4) values and norms. Amongst these, she asserted that the managerial systems provide mechanisms for knowledge creation and control, and the technical systems deal with the accumulation of this knowledge, including information as well as procedures. She argued that the better the alignment between the particular project and the incumbent knowledge set, the better the performance of the NPD. However, as technology progresses so rapidly, core capabilities may easily fade and soon turn into "core rigidities". Therefore, she added, it is also necessary for the firm to recognize that core capabilities can be recovered by diluting its former knowledge set: (1) abandonment; (2) recidivism; (3) reorientation; and (4) isolation.

Sinkula (1994) and Stanley and Narver (1995) discussed a three-stage process of organisational learning: (1) information acquisition, (2) information dissemination, and (3) shared interpretation. Based on this view, two key elements as well as two basic procedures in effect describe the nature of knowledge accumulation and organisational memory management (see Figure 3.3). The first element in the framework is the organisational information-processing model (see Figure 3.2) that acts as a window of information transmission between the organisation and the outside world. Such information processing activities include the transmission of information acquired through the transformation of primary or secondary ***data***, observation from surrounding ***phenomena***, and interaction with the external ***environment***. The second part of the framework is the ***assimilation of information***, that is, the ***learning*** and ***unlearning*** processes.

Figure 3.3 R&D Knowledge Accumulation and Organisational Memory Management



Source: the current study

These two processes represent the efforts of firms to create innovation-related knowledge through ***individual learning system*** as well to manage ***organisational memory***. They are also the interface for sharing knowledge between individuals and the organisation, during which both ***single-loop*** and ***double-loop*** learning can occur. These two types of learning require proper ***structural design*** that fosters ***knowledge creation*** (i.e, socialisation, articulation, combination, and internalisation) as well as allowing ***knowledge forgetting*** (i.e., abandonment, recidivism, reorientation, and isolation).

§3.3 The Concept of "Fit" and the Contingency situations in New Product Development Settings

The previous section highlighted information processing and knowledge accumulation as the cognitive core of product innovation. However, information processing and knowledge accumulation alone cannot guarantee successful NPD. The quality of managerial efforts also matters. Many scholars have stressed the concept of "fit" in determining new product success. For example, researchers have found that "product-company fit" (Cooper, 1979; de Brentani and Cooper, 1992), "overall company/project fit" (Cooper, 1992), or "business-project fit" (Lilien and Yoon, 1989) is one of the major factors influencing NPD performance. Also, the "product/ market fit" was known to be an important ingredient in ensuring final project results (Particelli and Killips, 1986; de Brentani and Cooper, 1992). Tushman and Nadler (1978) in addition suggested that, because different tasks involved different degrees of uncertainty (which in turn require different quality and quantity of information), the design of organisational information processing systems should be tailored to fit individual task specifications. In another article, Brockoff and Chakrabarti (1988: 167) stated that:

> *... the reasons for the failure of product innovation were embedded in complex multidimensional factors related to the fit between strategic behavior and the demands of the competitive environment.*

Indeed, the term "fit" has been widely recognised in literature. However, it was also widely criticized for its lack of careful operationalisation (e.g., Blalock, 1965; Van de Ven, 1979; Van de Ven and Drazin, 1985; Venkatraman, 1989; Iivari, 1992). Most previous researchers have verbally employed such a concept in their studies but stopped short of efforts to examine its validity. Venkatraman (1989) stated that the approach used in conceptualizing "fit" has enormous impacts upon the direction of theoretical development as well as upon the statistical results. He suggested that researchers should carefully define the concept of fit in their studies so as to allow a more in-depth validation of research methodologies. Along with his article, six perspectives of fit were identified, i.e., (1) fit as moderation, (2) fit as mediation, (3) fit as matching, (4) fit as gestalts, (5) fit as profile deviation, and (6) fit as covariation. He argued that each perspective was endowed with its own theoretical concepts, assumptions, suitable methodologies, and so embedded its own limitations.

Iivari (1992), in a similar manner, offered three basic interpretations for Venkatraman (1989)'s typology of fit, (1) the selection approach, (2) the interaction approach, and (3) the systems approach. He suggested that in employing the concept of fit, researchers should consider at least the following points for analysis:

- Contextual factors, i.e., the contingency factors;
- Information system characteristics, i.e., managerial structure;
- Effectiveness criteria used, i.e., performance;
- Type of fit, i.e., the above three approaches; and
- Methodology used in the research.

However, the central interest of these researches has been drawn to the understanding of the concept "fit". According to Iivari (1992: 7), the selection approach to fit referred to "an assumed premise that an organization must adapt to its context in order to survive or be effective." Here the fit was fully compatible with Venkatraman (1989)'s concept of "fit as mediation" where contextual factors decided managerial structure and managerial structure further decided the resultant performance. On the other hand, the interaction approach to fit highlighted the "interaction between pairs of organizational context-structure factors regarding performance or conformity to a relationship of context and design." In Venkatraman (1989)'s article this kind of fit was distinguished as having two different types of interaction, i.e., fit as moderation and fit as matching. The relationships between context, structure, and performance can be seen thus: (1) both context and structure influence performance; (2) context moderates the causality between structure and performance; or (3) the interaction (or match) between context and structure determines performance. While the above selection and interaction approaches of fit concerned only three variables, the systems approach regards the context-structure fit as a complex mix of variables in which "fit is the internal consistency of multiple contingency situations and structural and performance characteristics." It is possible for researchers to extract several internally consistent patterns of context and structure that eventually decided the final performance outcomes. This type of fit can also be analogised as Venkatraman (1989)'s "fit as gestalts", "fit as profile deviation", and "fit as covariation".

Most scholars admitted that product innovation is a highly uncertain task (e.g., Abernathy, 1971; Holland et al., 1976; Maidique and Hayes, 1984; Bonnet, 1986; Batson, 1987; Clark et al., 1987; Abetti and Stuart, 1982; Rogers, 1988; Bienayme, 1988; Bodensteiner et al., 1989; Pavitt et al., 1989: 64; van der Meer and Calori, 1989; Hall and Nauda, 1990; Pavitt, 1990; Iya and Akhilesh, 1992). Traditional management techniques are no more valid in such a situation (Souder, 1987: 239-41). Special management qualities are essential for coping with the dynamics of the marketplace including technological change. Because the factors in determining product innovation and its results are manifold and often multi-faceted, Quinn (1985) even called the management of innovation the controlling of chaos. The contingency situations in NPD therefore are highly complex and cannot possibly be represented by only one or two single variables. This suggests that the above selection or interaction approaches to fit may not be appropriate in the product innovation arena. With regard to "fit", the systems approach as stated by Iivari (1992) or the gestalts or the covariation perspectives in Venkatraman (1989)'s study may be better in describing the nature of NPD contingency situations.

The current study accepts the view that the dynamics in NPD are, in effect, the compound set of a variety of contingency variables emerging before and during development process. Successful NPD should present a consistent pattern of activities while controlling the complex interaction between contextual variables and managerial structures. In the current study, the managerial structures are represented by the structural design for organisational information processing and knowledge accumulation, while the contextual variables are categorised into two basic forms of NPD contingency situations, i.e., new product nature and environmental dynamics. Moreover, as previous researchers tended to prescribe contingency variables from a theoretical perspective, these may not fully represent real-world NPD situations. In the current study the gestalts and the covariation perspectives of fit are adopted as they more realistically reflect NPD contingency situations.

§3.4 Approaching a Contingency Model of NPD Information Processing and Knowledge Accumulation Management

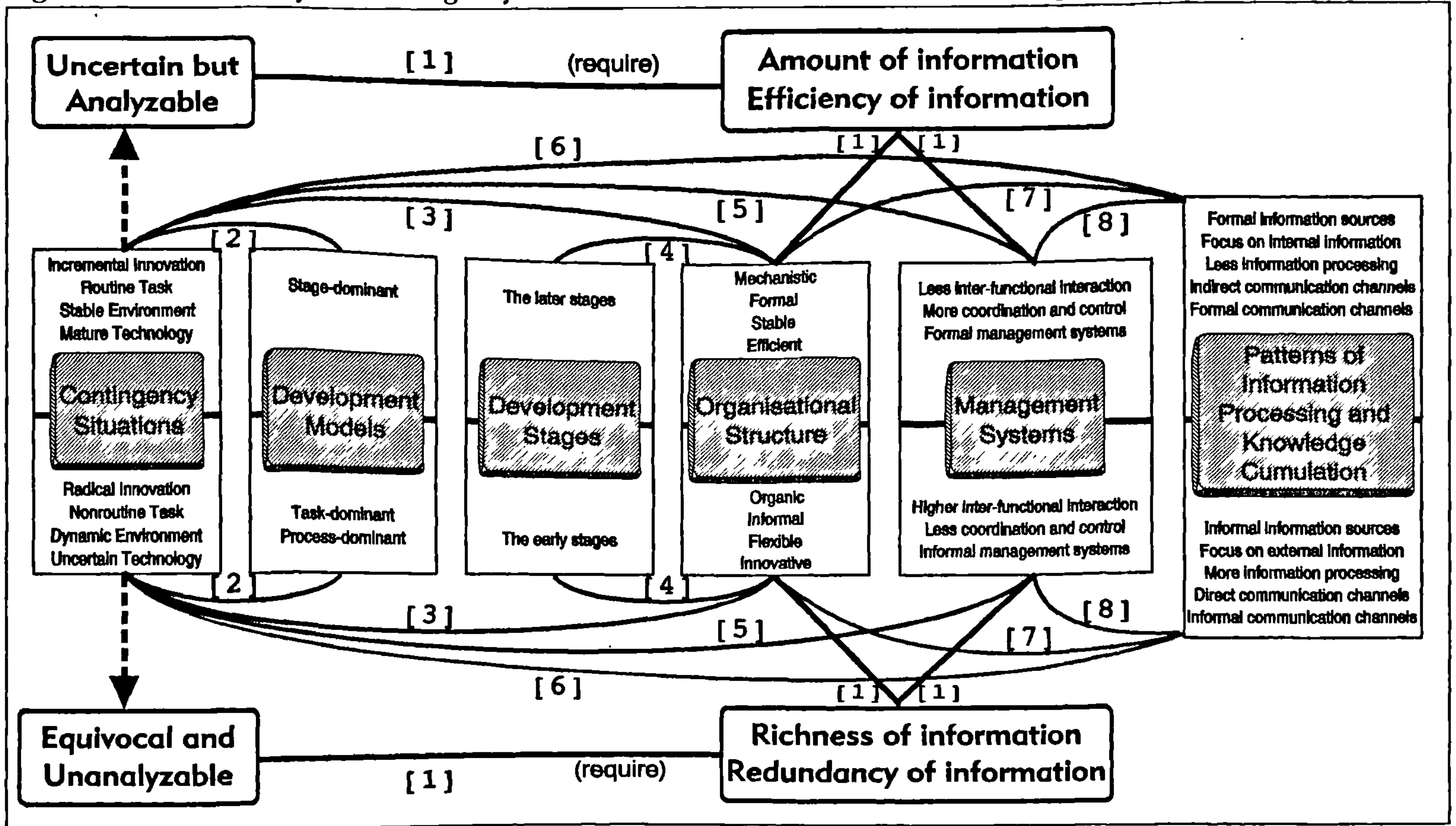
Chapter One raised the question as to whether or not it is beneficial for firms to tailor their new product development strategies in line with different project situations/conditions. Most scholars would accept that successful NPD projects are not managed in identical ways (e.g., Jermakowicz, 1978; Allen, 1986; Gupta et al., 1986; Rothwell et al., 1990; Rothwell, 1992). Many researches have also provided evidence that organisational NPD behaviour was largely contingent upon contextual variables (e.g., Fischer, 1979; Ito and Peterson 1986; Fleischer and Liker, 1992; Keller, 1994). This section summarizes previous work on this front and develops a contingency model for examining NPD information and knowledge management.

Figure 3.4 summarises previous major research into the contingent management of organisational information processing and knowledge accumulation. The framework stresses the differentiation of tasks and their relationships with information requirements. Scholars have long accepted that the usefulness of information lies in its ability to reduce uncertainty (e.g., Daft and Macintosh, 1981; Rogers, 1982; Daft and Weick, 1984; Sullo et al., 1985; Bonnet, 1986; Daft and Lengel, 1986; Batson, 1987; Bodensteiner et al., 1989; Moenaert and Souder, 1990; Bush, 1991; Menon and Varadarajan, 1992; Sambamurthy et al., 1993; Keller, 1994). As different tasks are often associated with different levels of uncertainty (which may be caused by either the incumbent environment or the task itself), information required for a particular task is therefore largely contingent upon the task's specific nature. Daft and Macintosh (1981), Daft and Weick (1984), and Daft and Lengel (1986) in addition differentiated such contingency situations into uncertain situations and equivocal situations, both assumed to be basic motivations of information acquisition.

According to their definition, "uncertainty" refer to a lack of information, while "equivocality" meant a state of ambiguity – a lack of understanding rather than a lack of information. They asserted that in highly uncertain, but still analysable, situations, it is necessary to acquire a greater amount of information in order to come to a decision. The major consideration in getting information hence is to increase the efficiency of processing information. On the other hand, when the situation is highly equivocal and unanalysable, the amount of information is not the key issue in information acquisition. Additional data may not be able to resolve anything. Worse, they may produce greater confusion.

Well designed organisational structure as well as management systems are needed to handle the amount and richness of information properly (Batson, 1987; Bush, 1991; Sambamurthy

Figure 3.4 Summary of Contingency situations in NPD Information Processing and Knowledge Accumulation



Sources: Based on the following articles and organised by the current study.

[1] Holland et al. (1976); Randolph (1978); Tushman (1978); Daft and Macintosh (1981); Daft and Weick (1984); Daft and Lengel (1986); Keller (1994). [2] Shrivastava and Souder (1987); Souder (1987: 217-37). [3] Jermakowicz (1978); Tushman (1979); Souder (1987: 217-37); Thurmond and Kunak (1988); Brown and Karagozoglu (1989); Fleischer and Liker (1992); Shenhar (1993); Keller (1994). [4] Tushman (1979); Johne (1984); Rothwell et al. (1990); Rothwell (1992). [5] Gupta et al. (1986); Hauptman (1986); Ito and Peterson (1986); Rochford (1991); Shenhar (1993). [6] Holland et al. (1976); Dewhirst et al. (1978); Jermakowicz (1978); Fischer (1979); Hauptman (1986); Ito and Peterson (1986); Souder (1987: 217-37); Thurmond and Kunak (1988); Brown and Karagozoglu (1989); Stevenson and Gilly (1991); Shenhar (1993); Keller (1994). [7] Jermakowicz (1978); Souder (1987: 217-37); Davis and Wilkof (1988); Brown and Karagozoglu (1989); Nonaka (1990); Rothwell et al. (1990); Rothwell (1992). [8] Souder (1987: 217-37); Rothwell et al. (1990); Rothwell (1992).

et al., 1993). Scholars believe that a specific structure or system design is necessary for acquiring and transmitting a particular quality and quantity of information (Daft and Macintosh, 1981; Daft and Weick, 1984; Daft and Lengel, 1986). Many researchers have also provided evidence of high inter-correlations among task types, the incumbent environment, information requirements, organisational structure, management systems, and patterns of information processing and knowledge accumulation (see Figure 3.4). Based on this previous work, the current study provides the following propositions and hypotheses.

Proposition 1:
NPD information requirements are contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

Previous researchers have stressed the importance of information in NPD. The more information gathered by the firm, the greater the likelihood of NPD success (Dougherty, 1990). However, studies also pointed out that information alone cannot guarantee new product success. Batson (1987) reported that the major problem in NPD information utilisation is the mismatch between NPD needs and the employed information systems. Scholars therefore suggested a contingency strategy for NPD information processing as we have mentioned above, that different new products called for different information. For example, Brown and Karagozoglu (1989) found that radical NPD tended to emphasise the processing of technology-related information while the incremental ones seemed to focus more on market-related information. Hence the first set of hypotheses:

Hypothesis 1.1
Management's perceived importance of a specific type of information required for successful NPD projects varies significantly with the type of new product project undertaken.

Hypothesis 1.2
Management's perceived importance of a specific type of information required for successful NPD projects varies significantly with the dynamics of its incumbent marketplace.

Hypothesis 1.3
For successful NPD, the actual efforts spent in acquiring a specific type of information vary significantly with the type of new product project undertaken.

Hypothesis 1.4
For successful NPD, the actual efforts spent in acquiring a specific type of information vary significantly with the dynamics of its incumbent marketplace.

Proposition 2:
NPD information acquisition behaviour is contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

Projects in different situations are often faced with a different degree of uncertainty and therefore require a different quality and quantity of information. The underlying determinants of the quality or quantity of information are information sources and acquisition behaviour. As early as forty years ago, Johnson and Jones (1957) highlighted the relationships between NPD types and corresponding information sources. They stated that relatively new NPD projects would consume more information outside the scope of their present business. Subsequent studies provided even more support for such a contingent NPD approach to gathering information. More (1978) reported that firms tended to access more secondary information when the product innovation is less novel in both the marketplace and the employed technology. Fischer (1979) compared the "nonroutine" with the "routine" R&D projects and concluded that R&D managers tended to access more "unbounded" information (i.e., information acquired from outside the organisation) from informal sources. Brown and Karagozoglu (1989) also found that incremental NPD tended to focus on the processing of internal information while the radical ones paid more attention to utilizing external information sources. The following hypotheses are posed:

Hypothesis 2.1
For successful NPD, the selection of information sources varies significantly with the type of new product project undertaken.

Hypothesis 2.2
For successful NPD, the selection of information sources varies significantly with the dynamics of its incumbent marketplace.

Hypothesis 2.3
For successful NPD, the key players in information acquisition vary significantly with the type of new product project undertaken.

Hypothesis 2.4
For successful NPD, the key players in information acquisition vary significantly with the dynamics of its incumbent marketplace.

Other scholars in addition stressed the role of timing in NPD information acquisition. For example, More (1984) proposed that the timing of market research during NPD is contingent upon the following situations:

(1) marketing task similarity (compared with the firm's prior experiences),
(2) relative competitive advantage (compared with other existing products in the marketplace),
(3) distribution complexity,
(4) customer perceived product risk, and
(5) development complexity.

He asserted that if (1) or (2) is high, firms tended to carry out market research much later. On the other hand, when (3), (4), or (5) is high, much earlier market research will be necessary. Although this study investigated only the implementation of market research in NPD, one can extend its applicability to the acquisition of other types of information to facilitate NPD. Hence, the following hypotheses:

Hypothesis 2.5
For successful NPD, the timing for information acquisition varies significantly with the type of new product project undertaken.

Hypothesis 2.6
For successful NPD, the timing for information acquisition varies significantly with the dynamics of its incumbent marketplace.

Proposition 3:
NPD information transmission patterns are contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

The mode of information transmission also influences the quality and quantity of information utilisation. Previous researchers have reported that the interaction between the information provider and the information user strongly influenced the effectiveness of information utilisation (Zaltman and Moorman, 1988; Moorman et al., 1992, 1993). In the NPD situation, such an interaction is often achieved by the design of organisational structure and management systems, which consequently determines the degree of functional coupling as well as the level of information redundancy. According to Levinson and Moran (1987), one of the most significant activities in R&D management is to maintain an appropriate balance of loose and tight coupling between different functions. They argued that because different phases of NPD tend to encounter different situations with different managerial requirements, a contingency approach in controlling functional coupling is necessary to gain effective information transmission. In a similar manner, Ansoff and Stewart (1967) also observed that successful firms tended to employ different degrees of "downstream coupling" when managing different types of NPD, in an attempt to assure a suitable level of functional communication and cooperation.

Indeed, although there is still a lack of systematic investigation, evidence suggests that NPD information transmission should be tailored to the contextual variables. For instance, Stevenson and Gilly (1991) suggest that the more ambiguous a problem, the more effective is the use of informal communication channels. Similar remarks can be found in Souder (1987: 217-37) and Brown and Karagozoglu (1989): in the cases of radical innovations, a higher degree of information redundancy is much more appropriate compared to the situation in incremental ones. This point of view is also supported by Nonaka (1990) and Bowonder and Miyake 1992ab) in observations of Japanese experiences. They found that the higher the level of information redundancy during NPD, the stronger the innovativeness of the firm. Hence, this study proposes the following hypotheses:

Hypothesis 3.1
For successful NPD, the extent of departmental coupling during product innovation varies significantly with the type of new product project undertaken.

Hypothesis 3.2
For successful NPD, the extent of departmental coupling during product innovation varies significantly with the dynamics of its incumbent marketplace.

Hypothesis 3.3
For successful NPD, the level of information redundancy during product innovation varies significantly with the type of new product project undertaken.

Hypothesis 3.4
For successful NPD, the level of information redundancy during product innovation varies significantly with the dynamics of its incumbent marketplace.

Hypothesis 3.5
For successful NPD, the nature of communication channels employed during product innovation varies significantly with the type of new product project undertaken.

Hypothesis 3.6
For successful NPD, the nature of communication channels employed during product innovation varies significantly with the dynamics of its incumbent marketplace.

Proposition 4:
Approaches for NPD knowledge management are contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

The above discussions centred on the management of information processing and proposed a contingency approach to information management, the latter being far more appropriate in the case of NPD. However, product innovation is not only concerned with information processing but also knowledge accumulation (e.g., Nonaka and Johansson, 1985; Takeuchi and Nonaka, 1986; Ealey and Soderberg, 1990; Pavitt, 1990; Nonaka, 1990, 1991; Ghoshal and Butler, 1992; McKee, 1992). Although previous researchers have seldom investigated the contingency model of NPD knowledge management, by referring to the case of information processing, one could arguably assume that the contextual variables also influence NPD knowledge creation and accumulation. Here NPD knowledge management can be seen as two-fold, i.e., information assimilation (knowledge creation) and knowledge accumulation, these two activities being supported by well-managed information processing. Successful NPD should reflect proficiency in the adjustment of managerial arrangements (e.g,. project management systems, information sharing mechanisms) to foster information processing, information assimilation, and knowledge accumulation so as to cope with the different project situations.

Hypothesis 4.1
For successful NPD, the managerial arrangements for facilitating information processing vary significantly with the type of new product project undertaken.

Hypothesis 4.2
For successful NPD, the managerial arrangements for facilitating information processing vary significantly with the dynamics of its incumbent marketplace.

Hypothesis 4.3
For successful NPD, the managerial arrangements for facilitating information assimilation vary significantly with the type of new product project undertaken.

Hypothesis 4.4
For successful NPD, the managerial arrangements for facilitating information assimilation vary significantly with the dynamics of its incumbent marketplace.

Hypothesis 4.5
For successful NPD, the managerial arrangements for facilitating knowledge accumulation vary significantly with the type of new product project undertaken.

Hypothesis 4.6
For successful NPD, the managerial arrangements for facilitating knowledge accumulation vary significantly with the dynamics of its incumbent marketplace.

Proposition 5:
Firms tend to tailor their NPD management systems to the internal and external contingency variables at the project, rather than corporate, level.

According to the assertion of a contingency approach to NPD management, firms tend to tailor their product innovation management to the dynamics of internal and external situations. However, there are at least two different levels of managerial adjustment that can be employed in such a contingency approach. For example, the firm may adapt its corporate management system so as to facilitate a certain new product development. Or alternatively, the firm may only modify the project-level structure or management systems to suit each individual NPD. As the adaptation or reformation of corporate management systems is often very costly and time consuming, these two levels of contingency strategy hold important implications for NPD management. Indeed, it is worth investigating to what extent a firm should shape itself to suit a particular NPD.

Organisational scholars have been suggesting adjusting organisational structures both at the corporate and project levels for coping with NPD contingency situations. However, previous studies have quite rarely differentiated whether their recommendations of contingency strategies were eventually at the corporate level or the project level. For example, Jermakowicz (1978) advised firms to use "productive" structures (e.g., pure line or divisional structures) for incremental NPD and "innovative" structures (e.g., matrix or task force structures) for radical ones. This seems to be a combination of both levels of organisational re-structuring. Even more ambiguously, some scholars simply used the term "organic structure" or "mechanistic structure" and asserted that each form of organisational arrangement was especially suitable for radical or incremental innovations respectively (Tushman, 1979; Souder, 1987; Thurmond and Kunak, 1988; Brown and Karagozoglu, 1989; Fleischer and Liker, 1992; Keller, 1994). Such a differentiation does not help to clarify the inquiry to what extent a firm should shape itself to suit a particular NPD.

Although there was a lack of direct evidence for guiding firms in deciding the required extent of NPD contingency management, several scholars did highlight the importance of contingency management at the project level. Allen (1986) showed that the geographic allocation of project team members should be considered according to different types of project. Many researchers have also suggested that the task-force form of team structure was most appropriate for highly radical projects (e.g., Thurmond and Kunak, 1988). Shrivastava and Souder (1987) and Souder (1987: 217-37) reported that firms tended to adjust their NPD process models (i.e., stage-dominant, task-dominant, or process-dominant) in accordance with different NPD contingency situations. In the current study, we assert that firms will tailor their NPD management systems to contingency situations at the project level rather than at the corporate level. As organisational re-structuring is highly time-consuming as well as very costly, it is unlikely that firms will shape themselves on a company-wide scale to suit every project. Moreover, it is possible for several projects that are different in nature to be carried out simultaneously therefore making the corporate managerial adaptation for every individual project impossible. It would be much more reasonable and efficient for firms to employ a flexible system that adjusts their team management models only at the project level. Therefore, the following hypotheses are offered:

Hypothesis 5.1
For successful NPD, firms tend not to tailor their NPD management models at the corporate-level for every specific type of product innovation.

Hypothesis 5.2
For successful NPD, firms tend not to tailor their NPD management models at the corporate-level in coping with the market dynamics of a specific project.

Hypothesis 5.3
For successful NPD, firms tend to tailor their NPD management models at the project-level for every specific type of product innovation.

Hypothesis 5.4
For successful NPD, firms tend to tailor their NPD management models at the project-level in coping with the market dynamics of a specific project.

Hypothesis 5.5
For successful NPD, the use of NPD process models for fostering product innovation varies significantly according to the type of new product project undertaken.

Hypothesis 5.6
For successful NPD, the use of NPD process models for fostering product innovation varies significantly according to the dynamics of its incumbent marketplace.

Hypothesis 5.7
For successful NPD, the project team composition varies significantly according to the type of new product project undertaken.

Hypothesis 5.8
For successful NPD, the project team composition varies significantly according to the dynamics of its incumbent marketplace.

§3.5 Summary of Research Hypotheses Development

This chapter proposes a contingency model of product innovation that centred on the management of information processing and knowledge accumulation. Such an assertion is ultimately drawn from the inquiry raised in Chapter One – whether it is beneficial for firms to tailor their new product development strategies to different project situations? If so, to what extent should a firm shape itself to suit a particular NPD? To answer these questions, we need to go further to investigate the nature of NPD management in real-world situations. Did successful NPD projects always follow the same pattern in managing product innovation? If this was not the case, why? Is there sufficient evidence to suggest that the variety of project management approaches is due to the need for coping with the contingency situations in NPD? If this is true, what are the contingency factors? How did those successful projects manage to adapt themselves in coping with these contingency situations?

The above inquiries are in effect key issues in both corporate strategic planning and NPD management. It is clear that NPD is crucial in deciding firms' competitiveness and even survival. It is also true that product innovation is highly difficult and risky and requires a great amount of corporate resources to support its long term development. However, there is indecision because of two difficulties. On one hand, in coping with the dynamics of external and internal project situations, a contingency approach to NPD management may be necessary so as to avoid unsuitable product innovation management. On the other hand, a contingent managerial approach may consume more corporate resources and managerial efforts than those of a uniform approach, which in turn, increases the risk of greater loss if the project fails.

This chapter has tried to organize the disparate findings from previous work in an attempt to construct a model that better describes the successful NPD management (see Figure 3.5). Several propositions as well as hypotheses are developed for the current empirical investigation. This study's key assumptions are:

(1) Organisations are open systems that allow a certain extent of interactions between the inside community and its outside world (e.g., Woodward, 1958; Burns and Stalker, 1961; Lawrence and Lorsch, 1969; Kast and Rosenzweig, 1973; Daft and Weick, 1984; Daft and Lengel, 1986; Keller, 1994).

(2) Information processing and knowledge accumulation are fundamental to effective product innovation (e.g., Allen, 1970; Rubinstein et al., 1976; Cooper, 1979; Maidique and Zirger, 1984; Nonaka and Johansson,

1985; Baker et al., 1986; Nonaka, 1990; McKee, 1992).

(3) Situations encountered by NPD projects are often different. However, there are certain patterns that can be identified to describe the variety of internal and external project situations (e.g., Venkatraman, 1989; Iivari, 1992).

Based on the above assumptions the current study therefore raises the following propositions:

(1) NPD information requirements are contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

(2) NPD information acquisition behaviour is contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

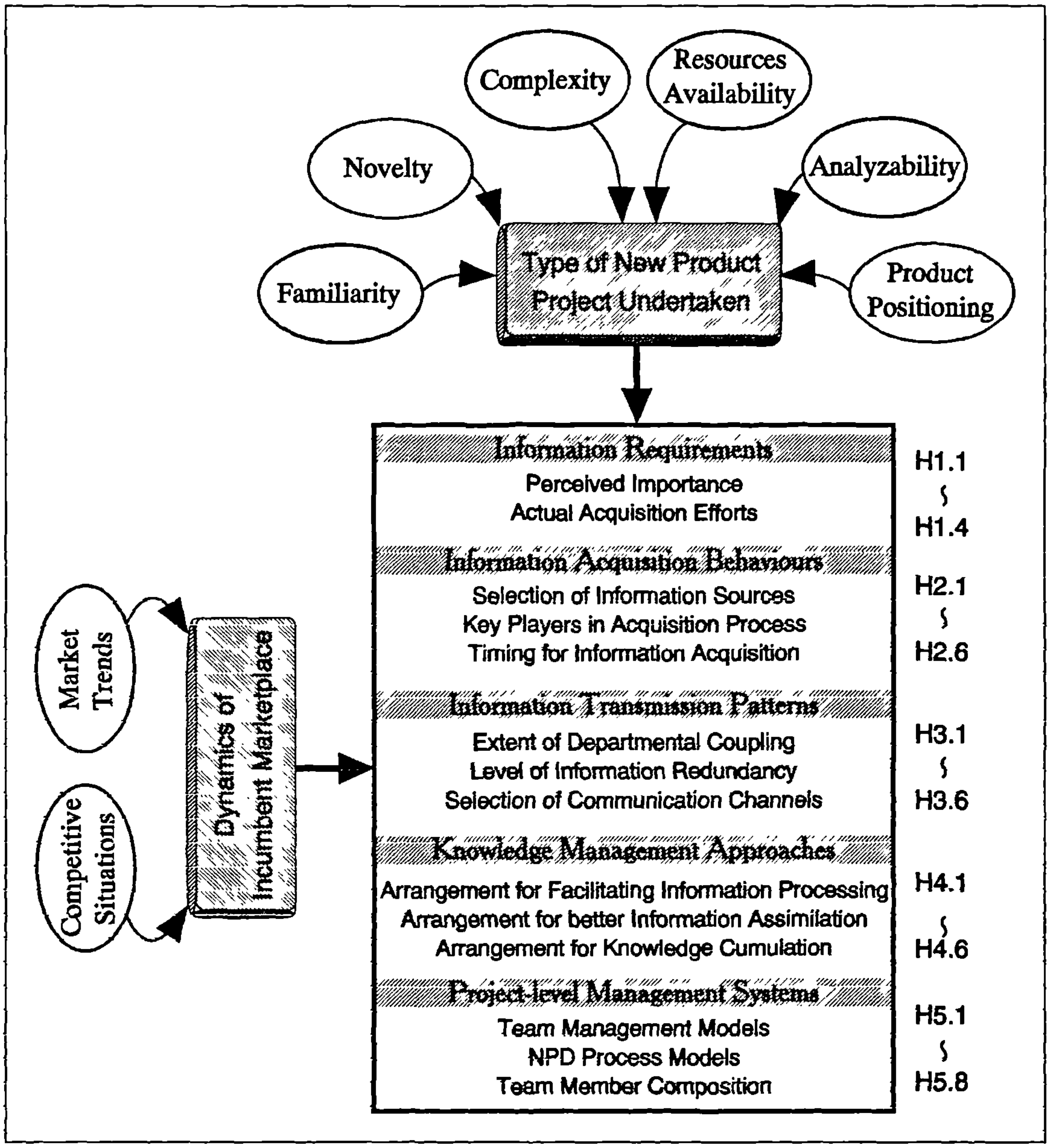
(3) NPD information transmission patterns are contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

(4) Approaches for NPD knowledge management are contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

(5) Firms tend to tailor their NPD management systems to the internal and external contingency situations at project, rather than corporate, level.

Along with the above propositions, specific hypotheses are developed and discussed in this chapter. Finally, to appraise the applicability of this study's proposed model, an empirical investigation was designed and implemented. The operationalisation of the research variables and the research methodology are discussed in the next chapter.

Figure 3.5 A Contingency Model of Information Processing and Knowledge Accumulation for Product Innovation



Source: the current study

Chapter Four

Research Design and Methodology

This chapter provides an overview of methodologies for examining the research propositions and hypotheses discussed in Chapter Three. The operationalisation of research variables is introduced so as to clarify the basic elements/concepts underlying the research hypotheses and the conceptual framework. The research instrument design is described and discussed, representing the measurements of different dimensions of these research variables. Statistical methods are selected based on the need to examine the research framework as well as the nature of the research data. Finally, this chapter presents the basic strategy for conducting the current study. The sampling frame, sampling design, and the collection of research data are described in detail.

4 Research Design and Methodology

§4.1 Introduction

The current study proposes a contingency model for managing product innovation. According to classical contingency theory, two factors explain the nature of environmental dynamics, i.e., external contingencies (e.g., market dynamics) and internal contingencies (e.g., task types). This study aims to confirm that successful NPD teams choose to pursue a different approach to information/knowledge management when encountering different project situations. To do so, the first step is to differentiate projects that encountered different project situations during NPD. By using statistical techniques such as Factor Analysis and Cluster Analysis, the current study clarifies the definition of project contingent situations and meanwhile classifies successful NPD projects into categories based on these internal and external contingent factors.

This chapter defines the research variables that are key to the hypotheses and the conceptual framework used by the current study (see Chapter Three). Operationalisation of Research variables is presented. The measurement of each variable is described along with the development of the research instrument. The statistical tools used for examining the conceptual framework and the variables are also presented. A detailed description of the sampling method is given. Finally, this chapter illustrates the validation techniques used to confirm the validity and reliability of data collection. The Limitations of the current research design are also discussed.

§4.2 Scope and Strategy of the Current Research

4.2.1 Research Scope

This study examines successful industrial experiences of product innovation management based on real-world observations. Two elements describe the focal object of the current research, i.e., (1) experimental development, and (2) product innovation.

Experimental Development

Practical innovation management often grouped the technological efforts into basic research, applied research, and experimental development. However, the efforts into basic and applied researches often require a great amount of resource input; they are constrained by the limited availability of resources in the firm or the society. As a result, in most countries the majority of such basic and applied researches are conducted by the public sectors, such as the universities and the research institutes, or supported by the national defence research projects. In the private sectors only the few very large corporations can afford to spend money in these arenas. Most firm-level innovative activities are limited to the experimental development, which requires fewer investments and brings on more predictable results in a relatively short time. The current study does not intend to limit its investigation of R&D efforts to the scientific researches in the public sectors or in the few very large firms. Rather, the focal interest is aimed at understanding the project-level development activities of firms in general.

Product Innovation

In firm-level technology management, classical studies stressed three basic types of innovative activity, i.e., organisational innovation, process innovation, and product innovation. These three activities in effect are highly correlated and together form the basis of firm-level technological innovation. Organisational innovation reflects the process of organisational re-engineering while facing the dynamics imposed by external and internal environment. Process innovation deals with the advancement of manufacturing procedures to reduce production costs, to smooth the production cycle, and to provide better production quality. Product innovation is the development of a new product that extends the utilisation of its current technology or satisfies customer needs. In some cases product innovation is a result of process innovation which brings new possibilities of product design; it is also possible that the development of process innovation is caused by the requirements raised from product innovation. Meanwhile, very often a certain level of organisational redesign is required so as to motivate product or process innovation. The current study seeks to understand how the winners manage their development activities to pursue effectiveness and efficiency in product innovation. The topics of organisational innovation and process innovation are jointly discussed, as they are closely related.

4.2.2 Qualitative versus Quantitative Research Approaches

Both qualitative and quantitative research methods are important tools for social studies. Qualitative methods use participant observation and unstructured, in-depth interviewing for identifying meanings, causes, and relationships of events in the real world. Kent (1993: 106) identified two basic features of qualitative research: (1) open-ended interview methods; (2) the collection of data which are largely qualitative and in the form of narrative rather than isolated statements. When adopting this approach the researcher makes direct contact with clients; the sample size is often small and not usually representative of a population; the major concern in the research is to understand a situation, rather than to measure the extent of its occurrence. Cooper and Braithwaite (1977) stated the major benefits of qualitative approach for social researches, i.e., it directly understands and interprets the nature of the real-world – a world based on experienced language context and complex behaviour. For example, by using qualitative methods, researchers can subjectively understand how people live, feel, think, and act, so as to understand the world from their perspectives. The major drawback of this approach lies in its inability to deal with complicated theoretical problems, as verbal data can only be handled by verbal analysis. Another disadvantage is its requirement of direct contact with the respondents, necessarily too limited to represent any particular population. Finally, the quality of data collection is largely dependent upon the experience and training of the researcher. Inexperienced interviewer can produce a faulty interpretation of the responses.

By contrast, quantitative methods measure the numeric meaning of social events by using experimental investigations. The collection of data is based on providing pre-defined questions to respondents and requesting answers that fit in with certain formats. The responses are systematically recorded in numeric form, which can later be analysed with statistical models. As the data type is numeric and the data formats are pre-defined, it is possible for the researchers to access a large sample size without direct contact with the respondents. The data can be easily integrated into information systems for easy comparisons and extrapolations, and provide better continuity when conducting longitudinal studies. Furthermore, by utilising the power of computer technology, researchers can deal with large numeric data sets efficiently and effectively. It is also possible to examine complicated theoretical relationships between variables, far more effectively than with the verbal analysis of qualitative data. However, there are also drawbacks embedded in the quantitative research approach. The major criticism to this approach is the question about the appropriateness of using scientific method to analyse people and social events. For example, Cooper and Braithwaite (1977) argued that there was a shift towards qualitative research because the blind-mind computer programmes and statistical models would never understand spiritual human beings. Scholars often commented critically that such "scientific" approaches of quantitative methods fail to deal with the differences between people and the objects of the natural sciences. Moreover, as the instrument for acquiring research data is intentionally pre-designed by the researcher, researcher bias may influence the validity of the instrument design. The observation of human activities by using such indirect instruments may distort the truth or may capture only superficial phenomena from the complexity.

Both research approaches discussed above are widely employed for social studies. Many researchers differentiated these two approaches and argued which is more appropriate for social studies. However, some scholars stressed that both approaches have their advantages as well as disadvantages; the key point lies in the appropriate matching of methods to situations. Kent (1993: 121) stated the suitable situations for using qualitative methods:

(1) The researcher does not know enough about a country or a market or some aspect of consumer behaviour to be able to design a piece of research, submit a worthwhile research proposal, or decide on the priorities and objectives of the research.

(2) The researcher wants to generate hypotheses or possible explanations before embarking on the main study.

(3) The researcher needs to design questionnaires in which the consumer perspective on, or images of, products and brands needs to be tested as these are not known in advance, or where the words, phrases or categori-

sations of markets or products need to be checked before proceeding to quantitative research.

From this point of view, qualitative methods are more appropriate for exploratory purposes before conducting large scale quantitative research. Such an approach reflects the belief of some researchers that both types of method are complementary with some areas of overlap. As stated by Blalock (1970: 45-6):

> *. . . techniques of participant observation are extremely useful in providing initial insights and hunches that can lead to more careful formulations of the problem and explicit hypotheses. But they are open to the charge that findings may be idiosyncratic and difficult to replicate. Therefore many social scientists prefer to think of participant observation as being useful at a certain stage in the research process rather than being an approach that yields a finished piece of research.*

Furthermore, scholars highlighted the similarity of qualitative and quantitative methods in many areas and therefore the qualitative data can, to some extent, be quantified (Bryman, 1992). For example, qualitative statements can be investigated by using content analysis, in which the frequencies of specific verbal objects in the statements are identified, counted, and treated as quantitative data for further analysis (Weber, 1983, 1984). Bryman (1992: 131-56) suggested nine approaches of blending quantitative and qualitative methods, which bring the greatest advantage for research design:

(1) *Triangulation*
A research approach that combines multiple observers, theoretical perspectives, sources of data, and methodologies to examine the same research problem. By combining both qualitative and quantitative methods the validity of research conclusions can be enhanced if the results from both methods provide mutual confirmation.

(2) *Qualitative Research Facilitates Quantitative Research*
As discussed above, the qualitative research acts as a forerunner to the formulation of research hypotheses and the development of research instruments for larger scale quantitative research.

(3) *Quantitative Research Facilitates Qualitative Research*
The quantitative research helps to select cases for further in-depth qualitative research.

(4) *Quantitative and Qualitative Research are Combined in Order to Produce a General Picture*
Qualitative research presents a process view of social life, while quantitative research provides an account of the regularities (i.e., the patterns of structure) of social life. A combination of both methods can produce a general picture of the problem domain and, therefore, bridge the gaps that cannot be filled by using either approach alone.

(5) *Quantitative Research Help to Establish the Generality of Qualitative Observation*
The researcher emphasizes his/her efforts mainly on the qualitative data and in the meantime employs the quantitative information as a means of establishing the generality of the qualitative observation.

(6) *Qualitative Research May Facilitate the Interpretation of Relationships between Variables*
Very often it is difficult to interpret the reason and direction of causal relationship between variables by quantitative methods. Combining qualitative methods in the research can provide an understanding of the processes and mechanisms which cause such statistical relationships.

(7) *Pursuing both the Macro and Micro Level of Research*
Qualitative methods are often viewed as best suited to the investigation of the micro level of social life; while the quantitative methods are conceived as better in establishing findings on the larger scale, the macro level. Combining both types of methods can bridge the two levels of analysis.

(8) *Regard Different Approaches as Necessary Stages in the Research Process*
Quantitative and qualitative research can be seen as relevant at different stages in the longitudinal research process. In the initial phase, qualitative research allows the investigator to explore the nature of the problem domain, the initial state of the research object, and conclude some initial findings. For the subsequent stages structured quantitative observation produces the major findings of the study. Finally the researcher has a chance to compare the results from both research approaches.

(9) *Hybrid Approach*
Combining several of the above approaches at a time.

The current study adopts the hybrid approach of combining both qualitative and quantitative methods in a two-stage research design. In the first stage, a qualitative exploratory study was conducted in an attempt to acquire initial knowledge about the research domain, the management of product innovation. The current conceptual framework, research hypotheses, and quantitative research instrument that were developed based on theoretical work were validated and refined through the first stage investigation.

The second stage of investigation, large-scale fieldwork, is the major part of data collection in the current study. As product innovation can be seen as an event as well as a procedure, to understand such an activity requires investigation into both its structure and processes. The current study investigates both the structure and the processes of product innovation by combining quantitative and qualitative techniques for conducting the fieldwork. Qualitative data were further quantified for statistical analysis in an attempt to establish the generality of the current research. In the meantime, the qualitative data also provide valuable insights into the rationalisation of the final statistical results.

4.2.3 Exploratory Study

The exploratory study for the current research consists of eight in-depth interviews of NPD cases with senior project members or overseas managing directors from four Taiwanese high-tech firms. The purpose of this exploratory study was to acquire initial knowledge about product innovation activities of the Taiwanese firms, in an attempt to provide necessary insights from practical experiences to validate and refine the conceptual framework, hypotheses, and research instrument of the current study. As this study did not intend to frame any hypothesis or to generalize from this exploratory study, the companies (and NPD cases) participating in the study were chosen from a list provided by the Board of Foreign Trade, Taiwan, without considering their representativeness to the population (i.e., convenience sampling).

The study was conducted during April and May 1993 in England. Information from eight NPD projects was acquired through in-depth interviews with members of the UK subsidiaries of four Taiwanese firms. All these informants have experience, directly or indirectly, of managing NPD projects. Each interview lasted between two to four hours and was generally guided by an interview structure with a set of given questions. By design, there were three major points in each interview. First, the informants were requested to describe the general approaches of corporate innovation activities of each firm, in an attempt to understand how firms organize their managerial efforts to better utilize and enhance their core competencies. Secondly, each interview centred on discussing a NPD project that was carried out and launched in the previous five years. Such a NPD project was chosen by the informant(s) in which both successful and failed cases were considered. Ten information types (e.g., market, consumer, technology, manufacturing, etc.) were highlighted as the focal objects of NPD information processing. How firms organized their NPD teams and in what mode the team acquired and communicated this NPD-related information within and beyond the firm were reviewed in detail. Finally, the questionnaires were presented to the informants for comments and suggestions.

The exploratory study gathered information of eight NPD projects from four Taiwanese high-tech firms, in which four were successful cases and the other four failed. Three of them were categorized as high-novelty projects and the other five were incremental ones. The preliminary findings from these case studies support the conceptual framework of the current study. First, there was clear evidence to suggest that successful and unsuccessful NPD projects differed in their pattern of information acquisition, transmission, and utilisation. For most information types, the failed cases reflected a lower enthusiasm for both information acquisition and utilisation. In the successful NPD cases, managers tended more to value the high impact of quality information upon their management of product innovation than did their counterparts involved in the failed projects. This suggests that proficiency in NPD information processing may be an important predictor of NPD performance. Secondly, for the successful cases, there was strong evidence to show that firms tended to adapt their NPD information processing strategies to project types. Different types of NPD projects seemed to seek out different types of information to facilitate their development process. Furthermore, the radical and incremental innovations also showed quite a different pattern of NPD information transmission during product development. This confirmed the current study's assertion of a contingent viewpoint of new product development. The excellence of these successful cases in the exploratory study may be largely the result of well-designed contingent strategies for NPD information management.

4.2.4 The Fieldwork

Encouraged by the preliminary findings from the exploratory study, a large-scale fieldwork based on the representative sampling design was adopted to acquire a more in-depth insight into NPD knowledge management (which includes information processing and knowledge accumulation). Such a fieldwork design aims to be sufficiently qualitative to provide the necessary depth in investigating the entire NPD knowledge management process, and quantitative enough to allow the revealing of complex relationships among variables. For example, the NPD information processing process in the real-world situation is a complicated procedure. It is complicated because it incorporates several "agents" (such as the sources, informants, receivers, users) through a variety of "channels" (such as documentation, meetings, personal interactions, electronic messages) for transferring information and knowledge. It is contingent because different firms may use quite a different pattern of combination of these "agents" and "channels" at different NPD stages and for different NPD projects. It is procedural because the product innovation activity is continuous, which cannot be understood through a cross-section observation. As a result, the current study has to acquire procedural as well as structural data of NPD information processing activities by blending both qualitative and quantitative methods in the research design.

For the qualitative part of the research, informants were requested to describe the whole process of NPD knowledge management in detail, from idea generation to new product commercialisation, from project-level knowledge creation to corporate-level knowledge accumulation. Ten types of NPD-related information were highlighted for the discussions. The major events which occurred during NPD that eventually determined the success or failure of the new product were also recorded, which provided intuitional insights for understanding the project. Some of these stories are presented as case studies in Chapter Ten. Moreover, by using Content Analysis as well as a specially designed instrument, the qualitative statements of practical NPD experiences were recorded and quantified. This information was later combined with the quantitative data for statistical analyses.

The quantitative part of the current research design developed and validated a quantitative instrument for acquiring firm-level as well as project-level information. For the firm-level information, informants were requested to provide information about corporate R&D input, overall R&D performance, the impact of NPD upon the corporate-level operation, and the strategic orientation of general management. For the project-level information, informants were requested to provide information concerning the amount of resources allocated for the project (e.g., manpower, budget, and time), to measure project performance in terms of its strategic goals, to discern the project characteristics based on its internal and external contingent situations, and to rate the impact and quality of each of the ten information types specified by the current study.

By combining the qualitative and the quantitative data acquired from a random sampling design, the current study is able to investigate a large set of representative samples, while achieving both width and depth of observation. The qualitative data also provide further insights to help rationalisation of statistical results. Although the main body of the empirical analyses is based on the utilisation of computer technology and quantitative models, "blind research" or "senseless analysis", which has been criticized by the qualitative-method promoters is avoided.

§4.3 Variable Operationalisation and Instrument Design

4.3.1 Introduction of Instrument Design

This section discusses the variables used in the conceptual framework as well as in the research instruments. The research instruments in the current study consist of two questionnaires (see Appendix IV and V). The first questionnaire uses a semi-structural design for acquiring quantitative data. This questionnaire was designed in three parts. In part one, the informants were requested to provide information concerning the profiles of corporate-level managerial approaches as well as R&D activities. Parts two and three deal with project-level information. In part two the informants were requested to provide project details in terms of development cycle time, development cost, and estimated product life cycle. Informants were also requested to rate the perceived importance of seven pre-defined NPD strategic goals and to measure the performance of the project in achieving each goal. The internal and external contingent situations that influenced the nature of the project were also manifested in part two. The informant was requested to indicate his/her observation about the project at the time of product launch.

In part three of the questionnaire the informants were requested to provide information concerning the information processing activities for each information type (in total ten information types were pre-defined) during product development. Informants were asked to rate the impact of each information type upon the project, to rate the quality of each information type acquired during product development, and to indicate the NPD stages, in which, if any, each information type was actually acquired. One special technique was used for dealing with the complexity of NPD information processing for each information type. In the questionnaire there were pre-defined lists of information sources, initial information formats, information providers, information transmission channels, and information users. The informants were requested to draw lines to link items to items in the lists to describe the relationships among the above lists concerning actual information processing during NPD. In this way, the flow of each type of information from the source, passing through informants and communication channels to the end users, was diagrammatically represented. They can later be quantified (e.g., to count the number of information paths that actually occurred during NPD) for statistical analyses. However, as the collection of data was based on a *post hoc* research design, it was not possible for the informants to recall every detail of previous NPD projects. As a result, only the most significant information flows were recorded for analyses, although the current study fully recognizes a highly complicated communication network exists during NPD.

The second questionnaire is a series of open-ended questions (i.e., interview structure) for acquiring qualitative data. The interview structure was designed in two parts; part one questions deal with the corporate-level R&D efforts and those of part two aimed at acquiring project-level information. For both parts, the basic structure of questions is similar; the only difference lies in their focus on corporate-level or project-level activities. The major consideration of these questions centred on revealing the mechanisms for NPD information processing and knowledge accumulation. The informants were requested to describe the organisational arrangements, organisational learning, NPD process, team structure, departmental coupling, and external communications for corporate R&D efforts as well as for specific NPD projects.

4.3.2 New Product and New Product Development Process

New Product

In attempting to capture the nature of real-world new product development, the current study did not impose pre-defined typologies to influence managers' selection of new product type; rather, it was entrusted to the informants to define what they meant by "new product" so as to map such a concept from real-world practices. A set of descriptive variables (see Section 4.3.3) was employed to record the nature of the new products selected by the informants. In addition, respondents were asked to select new products developed and commercialized in the last five years, so as to ensure a comparable base among cases for analysis..

New Product Development Process

The current study defines new product development process as a series of tasks aimed at the creation of a new product. According to the literature, these tasks include: (1) Strategy Development, (2) Idea Generation, (3) Preliminary Assessment, (4) Concept Development, (5) Prototyping, (6) Trial and Test, and (7) Commercialisation (see Table 4.1). Moreover, the order of carrying out these tasks during NPD can be sequential, parallel, or concurrent, depending upon the process model used by the project (Shrivastava and Souder, 1987; Souder, 1987).

4.3.3 Independent Variables

Internal Contingencies

Twenty variables are used to describe the internal dynamics of new product development. These are measured by using the 9-point Likert-type scale (Appendix IV. Quantitative Questionnaire: Part Two - F). The informants were requested to rate to what extent they agreed with the following statements at the time-point of the product launch:

(A) Familiarity Measures

We were expert in marketing or selling this kind of product. (Q1)

We were expert in developing this kind of product in terms of technological know how. (Q2)

We were very familiar with the production of this kind of product. (Q3)

Table 4.1 The Core Activities in New Product Development

NPD Stages/Tasks	Possible Activities
Strategy Development	✏ Core Technology Setting ✏ R&D Scale Setting ✏ R&D Resource Allocation ✏ Long Range R&D Planning
Idea Generation	✏ Idea Gathering ✏ Initial Screening ✏ Test Idea
Preliminary Assessment	✏ Preliminary Technical Assessment ✏ Preliminary Market Assessment
Concept Development	✏ Concept Identification ✏ Concept Generation ✏ Test Concept ✏ Business/Financial Analysis
Prototyping	✏ Engineering ✏ Design ✏ Prototype
Trial and Test	✏ Trial Production ✏ Test Market/Trial Sell ✏ Pre-Commercialisation Business Analysis
Commercialisation	✏ Production Start-Up ✏ Market Launch

Sources: based on New and Schlacter (1979), Cooper (1983, 1988, 1990), Souder (1987), Rabino and Moore (1989), Ayal and Raban (1990), Dwyer and Mellor (1991), Rochford (1991), Rochford and Rudelius (1992), and the author's industrial experiences.

All the core technologies for developing this product were sufficiently available in our company. (Q10)

All the key components, systems, or materials for producing this product were sufficiently supplied by our reliable sources. (Q11)

(B) Novelty Measures

This was a highly innovative product – the first of its kind on the market by any firm. (Q4)

This was a highly innovative product – there were very few firms able to use this kind of technology for developing this class of product. (Q5)

This was a highly innovative product – there were very few firms able to use this kind of production process for manufacturing this class of product. (Q6)

(C) Complexity Measures

This was a very sophisticated project in terms of the complexity of project management. (Q7)

This was a very sophisticated project in terms of the technologies employed. (Q8)

This was a very sophisticated project in terms of the manufacturing process employed. (Q9)

(D) Commitment Measures

Compared with other projects in our company, this project was highly supported in terms of available budget. (Q12)

Compared with other projects in our company, this project was especially supported by the CEO. (Q13)

(E) Project Initiation

The Original idea for this project was initiated by the market or our customer, rather than the technical breakthrough from our R&D. (Q14)

(F) Project Analysability Measures

In terms of technologies, we had a very clear idea from the very beginning of the project. We knew where the problems and solutions were. (Q15)

In terms of product specification, we had a very clear idea from the very beginning of the project. (Q16)

In terms of the definition of its target market and customer, we had a very clear idea from the very beginning of the project. (Q17)

(G) Product Positioning

Compared with similar types of competitor products, this product provided better functions or benefits to the end users. (Q18)

Compared with similar types of competitor products, this product provided better quality to the end users. (Q19)

Compared with similar types of competitor products, this product was priced much higher. (Q20)

External Contingencies

Five variables were used to describe the nature of the external environment encountered by a NPD project (Appendix IV. Quantitative Questionnaire: Part Two - D, F). Four of them employed the 9-point Likert-type scales for measuring the attitudes of the informants. The informants were requested to rate their opinions, from complete disagreement to complete agreement, about the following situational statements:

There was great demand in the market for this kind of product. (Q21)

The sales growth rate for this kind of product was predicted to be very high. (Q22)

Price competition had been a major marketing tool for this kind of product. (Q23)

There is a strong rival in the market for this kind of product. (Q24)

Informants were also requested to estimate the potential product life cycle of the new product. That is:

Estimated product life cycle of this product: ____ months. (Part Two: D)

4.3.4 Dependent Variables

Information Acquisition

Information acquisition is a process that incorporates activities such as defining information requirements, identifying information sources, and assigning the information acquisitors. In defining information requirements for NPD, the current study proposed a list of ten information types that were believed to be highly important for product innovation (see Table 3.2 for a more detailed theoretical background). These information types include:

(1) Goal/Strategy Related Information,
(2) Market Related Information,
(3) Regulation, Law, and Industrial Standard,
(4) Supplier, Component Related Information,
(5) Competitor Related Information,
(6) Customer Related Information,
(7) Cost/Price Related Information
(8) Product Related Information,
(9) Technology, Science Related Information, and
(10) Manufacturing Related Information.

Three variables were employed to measure the state of information requirement for each information type, i.e., the impact of information upon NPD, information quality, and the actual acquisition activity. By using the 9-point Likert-type scale, informants were requested to rate their attitudes in terms of the following two questions:

> Compared with other NPD projects, how would you rate the necessity of this information to the project? (Appendix IV. Quantitative Questionnaire: Part Three – A)
>
> Overall, how would you rate the sufficiency and quality of this information acquired or generated for researching and developing this project? (Appendix IV. Quantitative Questionnaire: Part Three – B)

Furthermore, informants were requested to indicate the NPD stages if a specific type of information was actually acquired. If the specified type of information was not acquired exclusively for the project, informants were also requested to indicate whether this information was totally ignored, or acquired for other projects, or an inheritance from preceding projects.

> According to the following NPD tasks or stages, what were the major stages for acquiring or generating this information for the project? – Multiple choices, please tick your answers (Appendix IV. Quantitative Questionnaire: Part Three – C)

In identifying NPD information sources, the current study proposed a list of information sources that were frequently cited by the previous researchers (see Table 3.1 for a more detailed theoretical background). These information sources include: (1) Outbound Sources, such as public sources, fairs/shows/exhibits, customers, suppliers, competitors, distributors, consultants, research institutes, affiliated companies; (2) Inbound Sources, such as subsidiaries, information centre, top management, R&D teams, other departments. The informants were requested to indicate the sources that were used for acquiring each type of information during NPD.

A list of possible candidates for information acquisition was also provided by the current study, i.e., Top Management, R&D, Marketing/Sales, Purchasing, Manufacturing, Service, Finance, and others. The informants were requested to indicate who was responsible for acquiring each type of information during NPD.

Information Transmission

Variables concerning information transmission investigate communication patterns during NPD. There were three considerations for this purpose, i.e., (1) the extent of departmental coupling for NPD information transmission, (2) the level of information redundancy during information transmission, and (3) the kinds of communication channel used. As stated in Section 4.3.1, a special technique was used to map diagrammatically the information flows of each information type from information sources to end users. The current study was therefore able to count the number of functional departments that participated in transmitting NPD information (i.e., to measure the extent of departmental coupling); the number of paths (information flows) and the number of different kinds of channel used can also be counted (i.e., to measure the level of information redundancy). The use of communication channel types can also be identified through the diagrammatic mapping of information flows.

Knowledge Management

Knowledge management refers to the management of information assimilation, knowledge creation, and knowledge accumulation. The data for these variables were acquired through qualitative interviews and were converted into quantitative data for statistical analysis. For the purpose of discussion, the current study creates the following roles in NPD knowledge management:

(1) *Information Facilitator:* Any specific managerial arrangement that was used by the sample firms to smooth the sharing and the circulating of NPD related information.

(2) *Information Digester:* Any specific managerial arrangement that was used by the sample firms to improve the processing of NPD information into useful knowledge.

(3) *Knowledge Accumulator:* Any specific managerial arrangement that was used by the sample firms to accumulate knowledge or experiences learned from NPD projects.

The current study did not provide any reference list for the informants to identify the above roles. Information concerning these managerial arrangements was acquired through qualitative in-depth interviews. Subsequently the researcher used Content Analysis to identify and record the frequency and quality of the above roles from the qualitative information.

Other Managerial Arrangements for Product Innovation

Similar to the identification of the above knowledge management roles, the corporate-level as well as project-level NPD management approaches were observed through qualitative in-depth interviews.

(1) *Corporate NPD Management Model:* The structural design to define or clarify the corporate-level relationships, authorities, and responsibilities between R&D and other functional departments during NPD.

(2) *Project Team Management Model:* The structural design for project teams that defines the composition of team members, style of leadership, and the basic strategy for conducting the project.

(3) *Learning Approach:* The orientation of NPD organisational learning embodied in the corporate NPD management models and the project team management models. According to Organisational Learning theory, a structural design that encourages external integration and boundary spanning would increase the proficiency of ***double-loop learning***, while the promoting of within-unit single-discipline information sharing could facilitate ***single-loop learning***. The mechanism of double-loop learning highlights the need for self-reflection and self-correction of activities, which suggests a strategic focus on the long-term effectiveness of operations. By contrast, single-loop learning stresses the importance of short-term efficiency in a specific domain of activities.

(4) *Learning Centre:* The key individuals, team members, or decision makers who are at the centre where NPD organisational learning takes place.

(5) *NPD Process Model:* The NPD process models were based on the theoretical work of Souder (1978, 1987) who believed that all NPD can be broadly classified into three distinct types of process models (which were labelled as Core Transfer Models in his original work). The three types of model are: (1) Stage-Dominant Models, (2) Process-Dominant Models, and (3) Task-Dominant Models.

(6) *Team Composition:* Describes how the NPD team was formed. Six variables were employed to describe the team composition: (1) team size (the number of team members), (2) the proportion of manufacturing people in the team, (3) the proportion of marketing people in the team, (4) the proportion of R&D people in the team, (5) whether there was a shift of team leadership during NPD, and (6) whether there was a redeployment of team members during NPD.

Performance Measures

The conclusion from previous academic work suggested that a multidimensional approach to performance measurement is highly necessary to reveal the nature of NPD management (Hart, 1993; Storey and Easingwood, 1993). In the current study both qualitative and quantitative methods were used to measure project performance. For qualitative measurement, informants were requested to indicate by using subjective verbal statement whether the project was eventually successful, uncertain, or had failed. For quantitative measurement, multidimensional function was used to decide new product performance. Seven pre-defined NPD strategic goals were provided to the informants with request for their ratings about the impact (weight) of these goals as well as the performance of the project in achieving these goals (see Table 4.2). Both ratings were measured by 9-point Likert-type scales. The multidimensional function can be represented by the equation:

$$P = \sum_{j=1}^{7} (I_j \times R_j)$$

where P is the performance score of the project, I is the perceived importance of each strategic goal, and R is the performance of the new product in achieving the goal.

This model depicts the NPD performance as both a multiplicative function of the achievement of NPD strategic goals and importance of these goals, and as an additive model across the various facets.

Finally, the time-point of deciding new product performance is another key issue of the current study. According to the sampling frame (which is discussed later in this chapter) the basic unit of this research is the complete NPD project. Therefore, the performance measurement of each sample case is based on the results of post-commercialisation performance. The dead projects, or the failed prototypes of a successful project, are not considered as failure cases because they are not included in the sampling frame.

§4.4 Statistical Methodologies

4.4.1 An Overview

Statistical tests depend on certain assumptions for their validity. For most parametric methods, there are three basic assumptions underlying the use of these techniques (Churchill, 1983: 500),

Table 4.2 Financial and Non-financial Goals for Measuring New Product Performance

Performance Measures	*Sources*
Financial Goals	
Sales	Cooper (1982, 1983b, 1984ab, 1985, 1987); Cooper and Kleinschmidt (1987abc, 1993); Hart and Service, 1988; Ayal and Raban (1990); Cooper et al. (1994)
Market Share	Rothwell et al. (1974); Cooper and Kleinschmidt (1987abc, 1993); Cooper et al. (1994)
Profitability	Cooper (1979, 1983b, 1984ab, 1985, 1987); Cooper and Kleinschmidt (1987abc, 1993); Calantone et al. (1993); Cooper et al. (1994)
Non-financial Goals	
Opportunity for entering a new business	Cooper and Kleinschmidt (1987abc)
Opportunity for entering a new market	Cooper and Kleinschmidt (1987abc); Storey and Easingwood (1993); Cooper et al. (1994)
Accumulating experiences, know-how, or technology for conducting other NPD projects in the future	the current study
To maintain or improve leading image in the market	Storey and Easingwood (1993); Cooper et al. (1994)

(1) independent samples,

(2) normal distribution of the characteristics of interest in each population, and

(3) equal variance in the two populations.

As a result, the research hypotheses, sampling design, and the data type decide the selection of statistical methodologies used in the current study. As the sampling design was based on the representative sampling approach with a relatively large sample size, the Central Limit Theorem can be applied to assume the nature of the samples as having a normal distribution[1] (a validation of sample representativeness is provided in Section 4.6.5). The major constraint of using multivariate methods imposed by the sample characters (normal distribution) was therefore removed. Moreover, as the data type of dependent variables used in the current study was based on interval scales (i.e., 9-point Likert-type scales) or ratio scales (i.e., observed frequencies), the use of analysis techniques was not limited to the non-parametric methods. In theory, there was in effect no statistical constraint for the current study to use any available method to examine the research hypotheses.

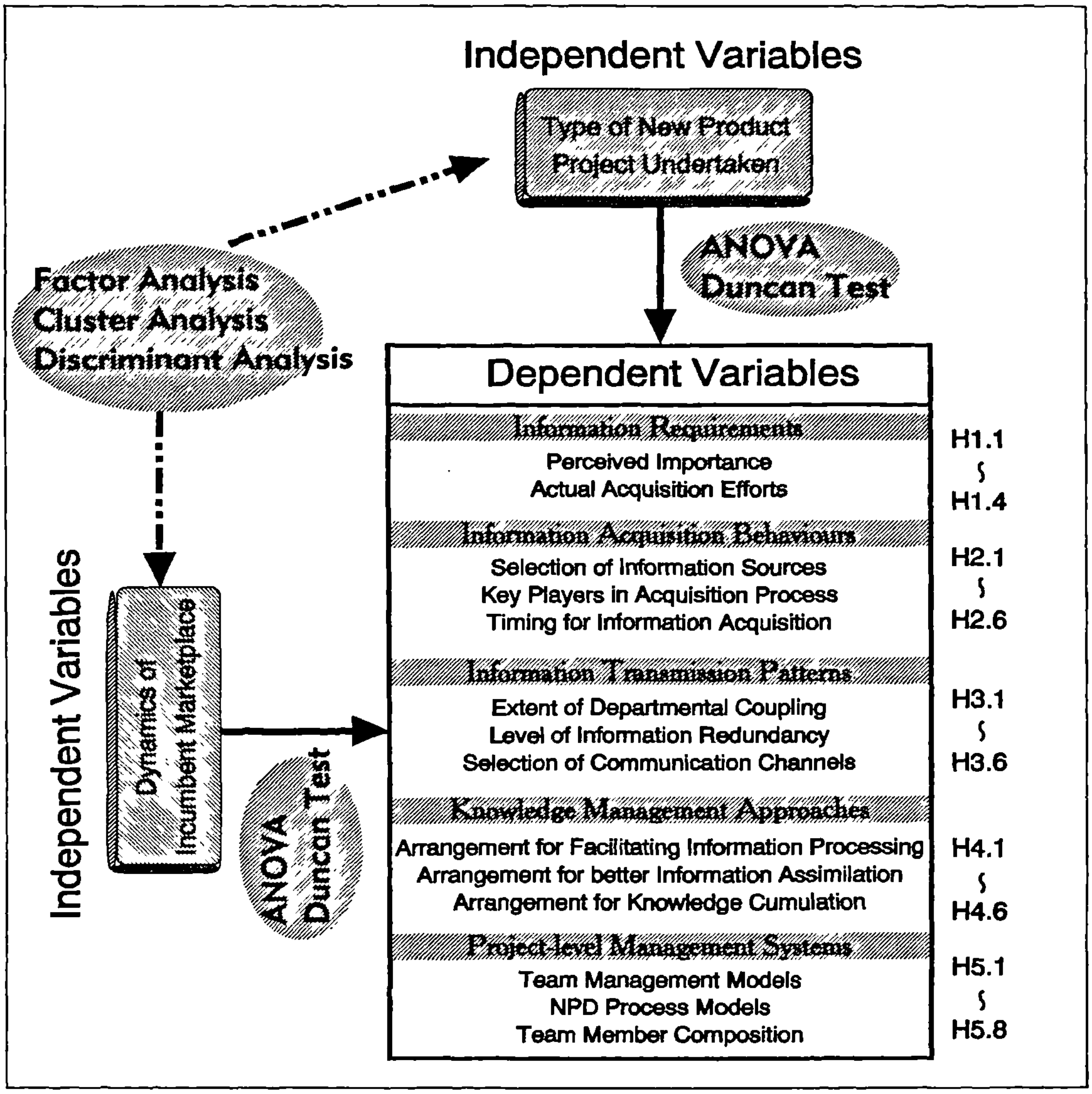
The basic approach for implementing statistical methods in the current study was to compare NPD knowledge management behaviour between different groups of samples. Figure 4.1 presents an overview of the choice of statistical methods. This approach is feasible given that NPD projects display specific attributes, so can be differentiated and categorized into groups based on their incumbent internal and external contingent situations. The current study used Factor Analysis to reduce the variety of contingent variables into factors. Cluster Analysis was conducted based on the factor loadings produced by the Factor Analysis and used to classify samples into groups. Discriminant Analysis was carried out to validate the classification of sample groups.

By categorizing samples into groups, the current study was able to compare the behaviour of sample projects between different groups. ANOVA and Duncan's Multiple Range Test were conducted to examine most research hypotheses. Besides these major efforts in hypotheses examination, other statistical methods such as the Descriptive Statistic, Chi-Square Test, and Correlation Analysis were also implemented to provide a descriptive overview of research samples, to verify the validity and reliability of instrument design, and to examine the representativeness of samples to the population.

This approach follows the methods widely used by strategic management studies, in which strategic groups are identified based on the common variables derived from Factor Analysis and the classification results from Cluster Analysis (e.g., Harrigan, 1985; McDougall, 1990). Other studies suggested that the use of Cluster Analysis to classify business units is valid (e.g., Horwitch and Thietart, 1987; Zahra and Covin, 1993). The same techniques were also employed by the studies of NPD screening models to identify key project determinants that can be used to predict new product outcomes (e.g., Cooper, 1985; Maidique and Zirger, 1984; Zirger and Maidique, 1990).

4.4.2 Univariate Analysis

Figure 4.1 Statistical Methodologies for Examining the Current Research Framework



Univariate Analyses, such as Descriptive Statistics, Chi-Square Test, t-Test, one-way ANOVA (*An*alysis *o*f *Va*riance), and Duncan's Multiple Range Test are useful tools for exploring the nature of data sets acquired from empirical fieldwork. The current study used Descriptive Statistics (e.g., frequencies, means, standard deviations) to validate the correctness of data coding, to reveal the characteristics of sample profiles, and to portray a general picture ofNPD knowledge management behaviour of the sample cases. T-Test was employed to examine the Concurrent Validity of the research instrument design. Multi-sample Chi-Square Tests (contingency tables) and one-way ANOVA were also used to compare the different characteristics of sample firms and population in an attempt to assure the representativeness of the research samples. Furthermore, one-way ANOVA and Duncan's Multiple Range Test were used as the major means to test the research hypotheses. The following is a brief description of the statistical methods used in the current study.

Multi-sample Chi-Square Test

Multi-sample chi-square test is an extension of chi-square tests for contingency tables, which examines whether a set of random samples is drawn from each of two or more populations, and in which all of them can be classified on the same nominal variable. For this purpose, the classification of populations is treated as the second variable in constructing the contingency table. The observed distribution of the nominal variable from these random samples is organized into rows. The statistical test is made to determine whether classification of these samples on the row is independent of classification on the column variable. Similar to the one-sample goodness-of-fit test, the multi-sample chi-square test uses the concept of expected frequencies that are derived from the marginal frequencies to calculate the chi-square statistic. Thus,

$$\chi^2 = \sum\sum\frac{(O_{ij}-E_{ij})^2}{E_{ij}}$$

$$E_{ij} = \frac{R_i C_j}{N}$$

Where O_{ij} = the observed frequency for cell in row i, column j
E_{ij} = the expected frequency for cell in row i, column j
R_i = the sum of the frequencies in row i
C_j = the sum of the frequencies in column j
N = the sum of the frequencies for all cells

The computer programme can calculate the chi-square statistic and directly generate the corresponding significance level having (r-1)(c-1) degrees of freedom (where r is the number of row and c is the number of column). If the chi-square statistic is significant (e.g., < 0.05), the hypothesis of independence between the row classification and the column classification is rejected. That is, the random samples are drawn from different populations.

ANOVA

ANOVA is a parametric statistical method that is based on the comparison of parametric variances between independent samples. It is used for testing the hypothesis that two or more samples were drawn from populations having the same mean. F statistic[1] is used to complete such comparisons. By aggregating the samples into a grand sample (thus, the distribution of the grand sample is F-distribution), the F statistic is calculated based on the extent of the total grand variance that is explained by the variance between samples. A large F statistic denoting a large portion of total grand variance can be explained as due to the variance between samples, rather than within each sample. That is, the difference between sample means is large and the variance within each sample is small. The following is the process of generating F statistic.

Given k samples are acquired from independent populations with each of them having n observations. Aggregating these samples produces a grand mean μ. From this, x_{ij} is the j^{th} individual observation of the i^{th} population, while α_i is the Factor Effect of the i^{th} population and ε_{ij} is the difference between x_{ij} and its population mean.

$$\mu = \frac{1}{k}\sum_{i=1}^{k}\mu_i$$

$$x_{ij} = \mu_i + \varepsilon_{ij} = \mu + \alpha_i + \varepsilon_{ij}$$

Therefore, the common variance of the grand sample can be calculated as s^2. In addition, the common variance can be further divided into between-group variances and within-group variances.

$$s^2 = \frac{\sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij} - \bar{x}_{..})^2}{nk-1}$$

$$= \frac{n\sum_{i=1}^{k}(\bar{x}_{i.} - \bar{x}_{..})^2 + \sum_{i=1}^{k}\sum_{j=1}^{n}(x_{ij} - \bar{x}_{i.})^2}{nk-1}$$

$$= \frac{SST}{nk-1} = \frac{SSC + SSE}{nk-1}$$

Where SST is the total sum of squared deviation; SSC is the sum of squares between groups; SSE is the sum of squares within the group. If the data are acquired from independent random samples of normally distributed and equally variable populations, the MSC (mean square between groups) and MSE (mean square within the group) can be calculated as unbiased estimates of the common population variance.

$$MSC = \frac{SSC}{k-1}$$

$$MSE = \frac{SSE}{k(n-1)}$$

Thus, from here the F statistic can be generated.

$$F = \frac{MSC}{MSE} = F_{(k-1,nk-k)}$$

t-Test

T-Test, or student t-Test, is used to test whether the means of two samples, and only two, are different. These two samples can be independent or related. However, there are important assumptions underneath the statistical method:

(1) the distribution of the measures in both samples is normal, and

(2) the variances of the two populations are equal.

T-Test is a special case of F-Test (ANOVA), in which exactly the same result is derived from both tests. The reason for such an algebraic equivalence between the two tests lies in the similarity of the t-distribution and the F-distribution, i.e., $t^2(v) = F(1,v)$. Moreover, t-distribution is very similar to normal distribution, in which a sample size larger than 30 can be treated as normal distribution (Yen, 1983: 139).

Duncan's Multiple Range Test

As the conventional techniques for comparing sample means are based on the comparison of common variances in aggregation, they cannot be used to compare the differences of means between all pairs of samples. Duncan's Multiple Range Test developed by Duncan (1955, 1957) provides the possibility of comparing all pairs of means. By using the Studentized Range Statistic, this method makes pairwise comparisons based on a stepwise order of comparisons identical to the order used by Student Newman Keuls Test, but sets a protection level for the error rate for the collection of tests. The decision rule to test whether there is a significant difference between treatment a and treatment b is as follows:

$$\left|\bar{T}_a - \bar{T}_b\right| \geq q \times r \times \sqrt{\frac{1}{n_a} + \frac{1}{n_b}}$$

$$q = \frac{\bar{T}_{largest} - \bar{T}_{smallest}}{\sqrt{MSE \;/\; n_h}}$$

$$n_h = \frac{k}{\sum_{i=1}^{k} \left(\frac{1}{n_i}\right)}$$

where T_a, T_b and n_a, n_b are the treatment means and sample sizes of group a and group b; q is the Studentized Range Statistic; r is the range between two means; n_h is the harmonic mean of the sample size of k sample groups; MSE is the unbiased estimate of within group mean square of the common population variance.

4.4.3 *Bivariate Analysis*

The current study uses bivariate Correlation Analysis to test the Concurrent Validity of instrument design. Correlation Analysis is a widely used tool for examining relationships (i.e., strength and direction) between variables. Bivariate Correlation Analysis assumes a linear relationship between two variables (e.g., X and Y) if the covariance of these two variables is not zero (i.e., Cov(X,Y) $\neq$ 0). Such a relationship is represented by the Linear Correlation Coefficient which is directly derived from the covariance of the two variables:

$$\rho = \frac{\mathrm{cov}(X,Y)}{\sigma_X \sigma_Y}$$

$$r = \frac{1}{n-1}\sum\left(\frac{X-\bar{X}}{s_X}\right)\left(\frac{Y-\bar{Y}}{s_Y}\right)$$

where ρ is the correlation coefficient of the population
r is the Maximum Likelihood Estimator of ρ, i.e., the correlation coefficient of the sample.

The r has a range between -1 and +1; a positive r means a positive linear relationship between the two variables, while a negative r denotes a negative linear relationship. However, a zero r does not mean that there is no relationship between the two variables. Rather, it only suggests that there is no linear relationship; it is possible that there is strong non-linear relationship between the two variables. There is no stable pattern of sampling distribution of r. If the sample size is less than 30 and ρ = 0 then r has a t-distribution; if the sample size is larger than 10 and $\rho \neq 0$ then r has a normal distribution.

4.4.4 Multivariate Analysis

One of the most important features of Multivariate Analysis is its ability to look at the inter-dependence between a large number of variables. For example, Factor Analysis can be used to uncover the common dimensions among a set of observed variables and therefore reduce the complexity of data sets. In a similar manner, Cluster Analysis and Discriminant Analysis can classify samples into subgroups and therefore provide a much clearer picture of the research objects. The current study employed these multivariate techniques to reveal the nature of environmental contingencies involved in new product development.

Factor Analysis

Factor Analysis is a technique for uncovering the underlying inter-relationship among the observed variables in an attempt to find a new set of variables that is fewer in number but sufficient in expressing the common nature of the original variables. There are two major approaches to identify the latent dimensions, i.e., the Common Factor Analysis and the Principal Components

Analysis. While both approaches are developed based on the aggregating of variables into linear combinations to represent the nature of the data sets, they are very different in terms of their assumptions. The Common Factor approach treats the observable variables as functions of the unobservable factors, while with the Principal Component approach the unobservable factors are expressed as functions of the observables. As a result, the Common Factor approach is better for identifying the number of common factors underlying the complexity of variables, while the Principal Component approach is used to derive small sets of linear combinations of the original variables that can explain most of the total variance.

As the current research design is aimed at obtaining a small set of factors that can best represent the nature of NPD contingencies, the Principal Component approach is adopted. Thus, the observation of variables in the sample space can be represented as follows:

$$PC_j = \sum_{i=1}^{p} W_{ji} X_i$$

where PC_j is the j^{th} principal component estimate (i.e., factor score); X are the observed variables; p is the number of variables;
W are the factor score coefficients of each variable.

By using the techniques of matrix algebra and multiple regression, eigenvalues as well as factor scores can be calculated (for the Principal Component method) and therefore the factors are extracted. However, very often the initial solution of factor analysis cannot clearly represent the data set as the resultant factor matrix is not simple enough for interpretation. At this point a factor rotation is necessary to achieve a simple structure of factor matrix. The rotated matrix of factor loadings represents an alternative interpretation of the data, in which they are both mathematically valid. Thurstone (1942, 1947) developed a set of criteria of "simple structure" as a guide to rotation.

(1) Each variable should have at least one zero loading.

(2) Each factor should have a set of linearly independent variables whose factor loadings are zero.

(3) For every pair of factors, there should be several variables whose loadings are zero for one factor but not for the other.

(4) For every pair of factors, a large proportion of the variables should have zero loadings on both factors whenever more than about four factors are extracted.

(5) For every pair of factors, there should be only a small number of variables with non-zero loadings on both.

(6) Any column of the factor loadings matrix should have mostly small values, as close to zero as possible.

(7) Any row of the matrix should have only a few entries far from zero.

(8) Any two columns of the matrix should exhibit a different pattern of high and low loadings.

Many approaches can be used to generate the rotated factor matrix; however, as they are not the focal interest of the current study, here the study will not further describe these applications.

The first step in implementing factor analysis is to produce a correlation matrix which provides a preliminary insight into the nature of the data set. As stated by several statisticians (e.g., Stewart, 1981: 56-7; Chatfield, 1991: 220-1), there are three situations that determine the validity of using this method:

(1) If most of the correlations in the matrix are small, the variables are essentially independent and so there is no point in using factor analysis.

(2) If most of the correlations in the matrix are large, the variables are possibly all measuring the same thing in slightly different ways and, therefore, it is not necessary to use this method.

(3) Only if the correlation matrix contains high, medium, and low correlations with no discernible pattern among them is a factor analysis applicable.

The best ways to estimate directly the suitability of using factor analysis are through the examination of the Kalser-Meyer-Olkin Measure of Sampling Adequacy (MSA) and the Bartlett Test of Sphericity. Stewart (1981: 57) stated that MSA is the most powerful method available for measuring sampling adequacy. It uses the partial correlation coefficient to examine the extent to which the variables belong together and are thus appropriate for factor analysis. A small MSA denotes that the relationship between a certain pair of variables cannot be explained by another variable (because the simple correlation coefficient is small and the partial correlation coefficient is large) and, therefore, a factor analysis is not appropriate. Kaiser and Rice (1974) provided the following remarks for using MSA:

90% +	marvellous
80% +	meritorious
70% +	middling
60% +	mediocre
50% +	miserable
50% -	unacceptable

The Bartlett Test of Sphericity examines whether the correlation matrix of the population is an identity matrix. If the population of variables that formed the correlation matrix are independent (i.e., the correlation matrix is an identity matrix), factor analysis is not suitable for the data set.

Another consideration in using factor analysis is to decide what number of factors should be extracted. Several criteria have been suggested to stop the extraction of factors. The most commonly used approach is the Latent Root Criterion, in which only the factors with an eigenvalue greater than 1.0 are extracted. However, the reliability of using this method has been criticized (Guttman, 1954; Stewart, 1981; Hair et al., 1992: 237). This method appears to be most accurate when the number of variables is small (i.e., < 40) and the communalities are high (Stewart, 1981: 58). Another widely used method in deciding factor number is the Cattell's Scree Test. The Scree Test is based on plotting the latent roots against the number of factors in their order of extraction. The maximum number of factors to be extracted is decided when the shape of the resulting curve becomes an approximately horizontal line. At the cutoff point the amount of unique variance has dominated the common variance structure.

Finally, deciding the significance level of factor loading is another important consideration. According to Hair et al. (1992: 239), factor loadings greater than 0.30 are considered significant; loadings of 0.40 are considered more important; and if the loadings are 0.50 or above, they are considered very significant. The larger the absolute size of the factor loading, the more significant the loading is in interpreting the factor matrix.

Cluster Analysis

Cluster Analysis is a means of clustering samples into groups. It is most popular in marketing researches in which customers can be grouped as having distinctive attributes and products can be categorized so as to implement market segmentation and product positioning. In effect, cluster analysis is not a single analysis; it is the name of a group of multivariate techniques aimed at identifying similar entities of objects so that each object is very similar to others in the cluster in terms of some predetermined selection criterion.

There are three major stages for implementing cluster analysis, i.e., partitioning, interpretation, and validation. At the partitioning stage, the researcher should decide the similarity measures and the clustering algorithms to be used. However, the purpose of using the measures and algorithms is to generate clusters that present the highest within-cluster homogeneity and the highest between-cluster heterogeneity. At the interpretation stage, the verbal statements of variables that were used to develop the clusters are examined so as to provide a label that can verbally represent the nature of the cluster. This is done by comparing the mean values of variables against each cluster; for each cluster, the tendencies of variables exhibit the nature of the cluster. At the final stage, the researcher should perform several analyses to ensure the validity of the cluster solution, e.g., ANOVA, Discriminant Analysis.

As suggested by many scholars, the major drawback in cluster analysis lies in its unstable results of classification; the methods (algorithms) used to generate clusters could strongly affect the clustering solution (Punj and Stewart, 1983; Chatfield, 1991: 41; Hair et al., 1992: 289). To address this problem, Punj and Stewart (1983) conducted a comprehensive literature review and provided several guidelines in the selection of similarity measures as well as clustering algorithms. They highlighted two sets of combination of measure and algorithm which were approved to generate the validity of the clustering result. The first set of combinations is by using the cluster method of "Average Linkage" with the similarity measure of "correlation coefficient". Many previous academic works have assured the validity of such a clustering method or such a combination (e.g., Cunningham and Ogilvie, 1972; Mezzich, 1978; Edelbrock, 1979; Edelbrock and McLaughlin, 1980; Blashfield and Morey, 1980). Another set of combinations is the use of "Ward's Method" with the "Euclidean Distance". Several studies supported the latter combination (e.g., Kuiper and Fisher, 1975; Blashfield, 1976; Mojena, 1977; Milligan and Isaac, 1980).

Nevertheless, the current study has tried a couple of combinations of the clustering method and similarity measures; they all produced similar classifications. The major difference between these treatments lies in the group sample size, where some combinations generated more even sample sizes among groups and others did not. Furthermore, the combination of "Average Linkage" and the "correlation coefficient" produced the best classification for the current study. Therefore, such a combination of clustering was selected to categorize the sample cases.

Discriminant Analysis

Discriminant Analysis is a statistical technique that can handle nonmetric dependent variables with a series of metric independent variables. The major purpose of this technique is to derive linear combination of the independent variables that can best discriminate between the pre-defined groups. Such a linear combination can therefore be used to determine (or forecast) the group to which an object belongs. To do so, the decision rule that maximizes the between-group variance and minimizes the within-group variance is used, in which they are represented as a ratio of between-group to within-group variance. The linear combinations of discriminant analysis therefore can be represented in the following form:

$$D = B_0 + \sum_{i=1}^{g} B_i X_i$$

where D = Discriminant Score
B = Discriminant Weights
X = Independent Variables

To validate the discriminant results, discriminant analysis also provides good facilities to compare group means, to visualize (to plot) the scattering of data sets at the discriminant dimensions, and to estimate the probability of a wrong classification. The current study uses discriminant analysis as a mean to validate the statistical results from cluster analysis. As the deriving of discriminant functions is not the focal interest of the current study, the discussions here will not cover the irrelevant topic of this technique.

Discriminant analysis uses group means to differentiate the distances between groups, and uses the Bayes' Rule to estimate the grouping probability. The calculation of distances between groups is by using the F-statistic:

$$D = B_0 + \sum_{i=1}^{g} B_i X_i$$

$$F_i = \frac{MSC_i}{MSE_i}$$

where MSC (mean square between groups) and MSE (mean square within group) is the unbiased estimate of the common population variance.
The calculation of B is based on the maximising of F. The resultant discriminant function will have an average D of 0 and an average MSE of 1.

A large F-statistic means a large difference between group means. Another similar indicator is the Wilk's Lambda. A small Wilk's Lambda suggests a large difference between group means. In the meantime, the calculation of F-statistic helps to estimate the probability of grouping a certain D into a particular group (e.g., group i). The Bayes' Rule:

$$P(G_i|D) = \frac{P(D|G_i)P(G_i)}{\sum_{i=1}^{g} P(D|G_i)P(G_i)}$$

where $P(G_i)$ is the prior probability;
$P(D|G_i)$ is the conditional probability;
$P(G_i|D)$ is the posterior probability).

Based on the above $P(G_i|D)$, the effectiveness of the discriminant functions can be identified by estimating whether the "grouped" cases are correctly classified. There are several approaches to achieve this goal. The most commonly used method is by randomly dividing the sample into two sub-samples and comparing the discriminant probabilities derived from these two sub-samples.

§4.5 Sampling Frame and Data Collection

4.5.1 A General Strategy

The major constraint of conducting inductive statistics is the assumption of the normality of research data sets. This is because the basic statistics such as t-statistic or F-statistic underlying most statistical inference techniques are based on the normality assumption. For example, the use of univariate analysis requires a univariate normality of the data sets, while the use of multivariate analysis needs to comply with the multivariate normality assumption. A significant violation of this assumption can largely weaken the validity of all statistical tests. As the current study intends to investigate the NPD behaviour of a certain population through a narrowed representative sample set, the major consideration in the sampling design is to satisfy the normality assumption.

Univariate normality requires that the observed variable has a normal distribution, while multivariate normality requires not only that all individual variables are normal in a univariate sense but also that their combinations are normal. Thus, if a variable is multivariate normal, it is also univariate normal. The normality of individual variables can help to increase multivariate normality, although not guarantee it. To achieve basic normality, a large sample size with a well designed representative sampling process is essential.

The basic sampling strategy of the current study is to acquire a sufficient sample size for multivariate analysis through a representative sampling design. Based on the Central Limit Theorem, statisticians suggested that a sample size with 20 to 30 observations is sufficient for univariate normality assumption, if the sampling design is representative enough (Chatfield, 1991; Roscoe, 1975; Yen, 1983). Therefore, the major concern in the current study is to ensure a sampling result that can honestly represent its population. A random sampling process is considered for this purpose. Furthermore, specific techniques were employed to increase the response rate and to enhance the correctness of data collection in an attempt to reduce possible non-sampling errors.

4.5.2 Taiwan as the Focal Interest of Research

The purpose of the current study is to reveal the nature of product innovation activities under project-level settings. The research unit is the project, rather than the firm. The major concern about the innovation activities is new product development, rather than basic or applied research. The current study also intends to acquire a data set that contains highly heterogeneous cases so as to examine the contingency hypothesis. Another concern is the accessibility of the research population. The population should be accessible to the researcher with an appreciable response rate. The researcher should be able to communicate with the sample firms freely without unnecessary guesswork while interpreting the qualitative information acquired from fieldwork. Based on the above considerations, the current study selected Taiwan, the researcher's home country, as the focal area for conducting fieldwork.

Background Knowledge

Taiwan, a small island located in south-east Asia among Japan, the Philippines, and China, has been one of the fastest growing areas in the world. The majority of Taiwanese are Chinese. They share the common culture, language, and ancestors that can be traced back to around 3,000 years ago. However, Taiwan was occupied by the Dutch 200 years ago; it was ceded to the

Japanese 100 years ago; it was under the protection and economic aid of the Americans after the Second World War. Such historical experiences developed in Taiwan a highly heterogeneous culture. Nevertheless, historically Taiwan has long been a province of China, although after the Chinese Civil War in 1949 it was separated from communistic mainland China and since then it has been governed by the Kuomintang government as a base for anti-Communist resistance.

With an area of 35,981 square kilometres, Taiwan is roughly the size of Holland. Domestic mineral resources are scarce, which leads to a wide reliance upon importing. Especially during the period of Japanese governance (i.e., from 1895 to 1945), nearly all the natural resources were exploited to support Japanese industrialization and military expansion. As a result, in the 1940s when the Chinese (Kuomintang) government took over the government of Taiwan, the island was barren and the people poor. In those days, for the common people, life was merely searching for a feed. Fortunately, by benefiting from a series of successful economic reforms with the industry of Taiwanese people, Taiwan quickly freed itself from poverty and came to riches. In the last 45 years, its average economic growth rate was 8.8%, a record far ahead of any other area in the world (see Figure 4.2 and Figure 4.3). In the same period, the economic system of Taiwan was transformed from an agricultural economy to an industrial economy, and even to a service economy. By 1994 Taiwan had become the 20th largest economic entity in the world, the 14th in international trade, and the second in terms of foreign exchange reserves. As observed by the economists:

> *Taiwan's record of economic growth has been phenomenal and the fruits of economic growth have been widely shared by all income groups on the island. Furthermore, the improvement of the material well-being of the people was accomplished in a climate of high consumer sovereignty without undue government control, high economic stability without serious inflation or unemployment, and financial solvency without foreign debt. Also, a high degree of structural transformation took place and caused a shift from primary to secondary industries. Some countries have done as well as Taiwan in some of these areas but few, if any, have done as well as Taiwan in all of them. (Hou and Gee, 1993: 384)*

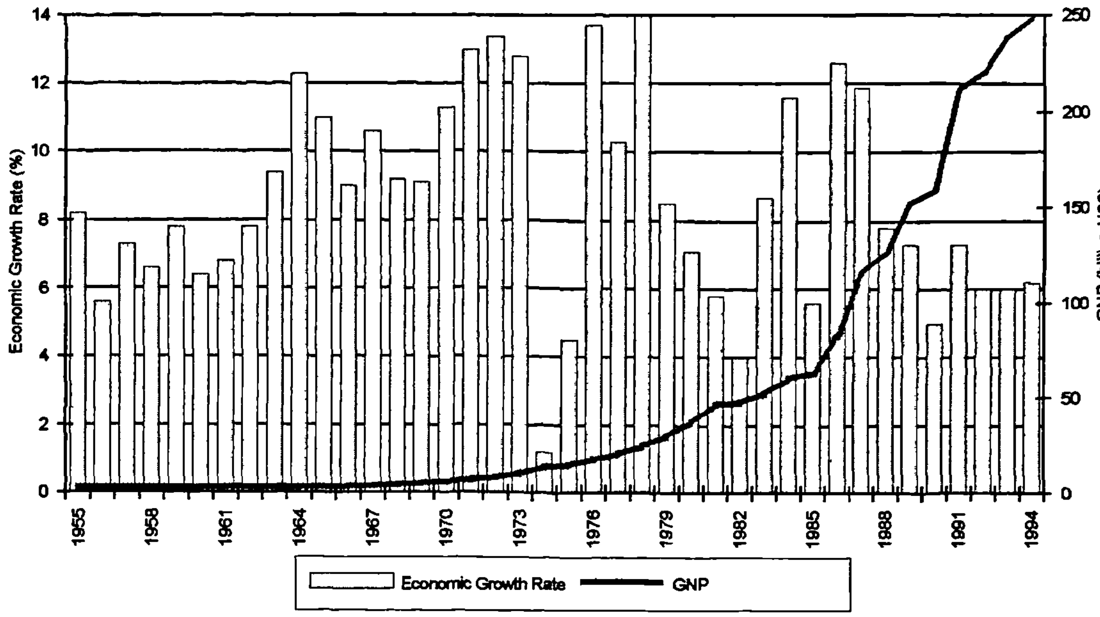
National R&D Activities in Taiwan

Education is one of the very important descriptors of Taiwan's economic growth, which to some extent contributes to the strength of Taiwan's R&D capability. American and Japanese elements have been combined with traditional Chinese Confucianism to mould Taiwan's highly demanding educational system. Freshmen are well prepared for university studies as their future is decided by intensive study habits as well as by passing severe examinations. Moreover, as Taiwan strives to catch up with Western and Japanese technologies, grade schools and high schools stress the great importance of science education. Students know well that only if they are proficient in sciences at school will there be good career prospects after graduation. Meanwhile, Taiwanese parents also impose tremendous pressure on their children to do well in school as this is the only hope for the family to improve their living-standard. Some of the best performing students will later go abroad to pursue higher degrees. Most of them select engineering or management for their further studies. This technologically-skilled fresh blood plays the key role in the high-tech industrialization of Taiwan.

However, the average national R&D expenditure in Taiwan is still far behind the highly industrialized western countries. Figure 4.4 shows that Taiwan's national R&D expenditure as a percentage of GNP was 1.7 in 1991, while those of the major western countries were above 2.5. One good sign is that the input of R&D manpower has gradually approached the level of some western counterparts such as the UK and France. In 1991 the density of researchers per 10,000 population in Taiwan was 22.5, which was not far away from the top performers in the world (about 30). The research quality from these researchers was good; in 1992, Taiwan was ranked as the 13th and the 10th in the world, in terms of the number of annual papers published, and the number of influential patents granted, in the US respectively (Indicators of Science and Technology, R.O.C., 1993).

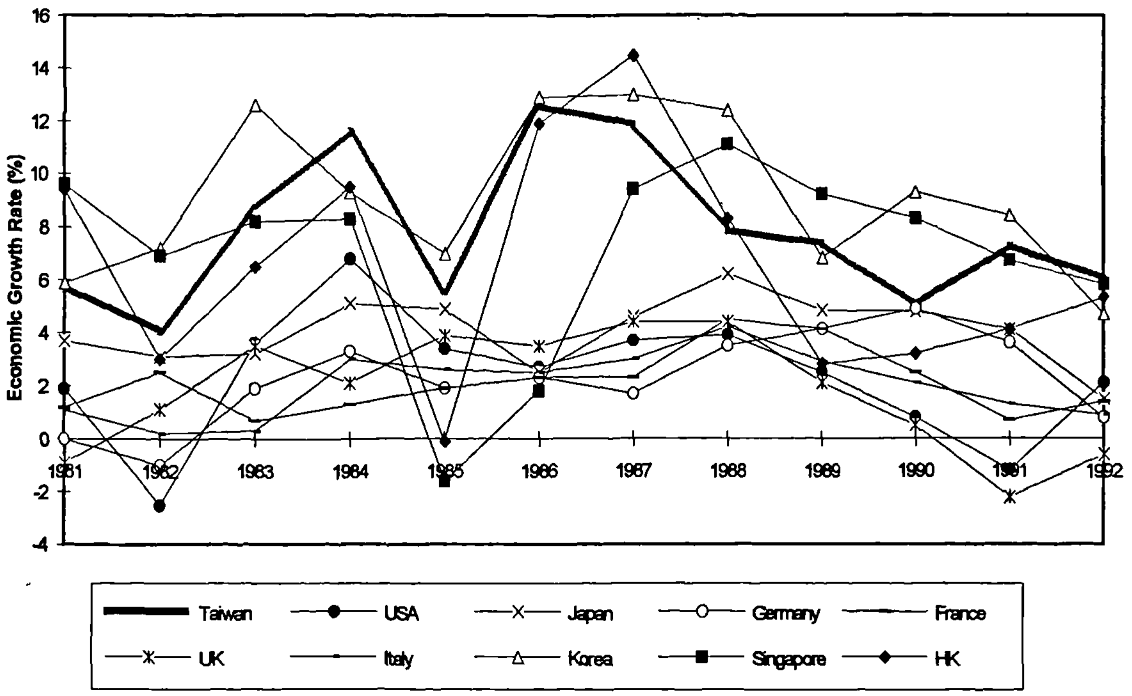
Over the years, although the total amount of annual national R&D expenditure has increased exponentially, the allocation of funds to some extent keeps to a similar pattern (see Figure 4.5). In 1991 about 11.5% of the funds were spent on Basic Research, while 40.3% and 48.2% were used in Applied Research and Experimental Development respectively. This reflects

Figure 4.2 The Path of Taiwan's Economic Growth



Source: Quarterly National Economic Trends: Taiwan Area, R.O.C., No.63, 1994, Directorate-General of Budget, Accounting, and Statistics, Executive Yuan, R.O.C.

Figure 4.3 Economic Growth Rates of Major Countries



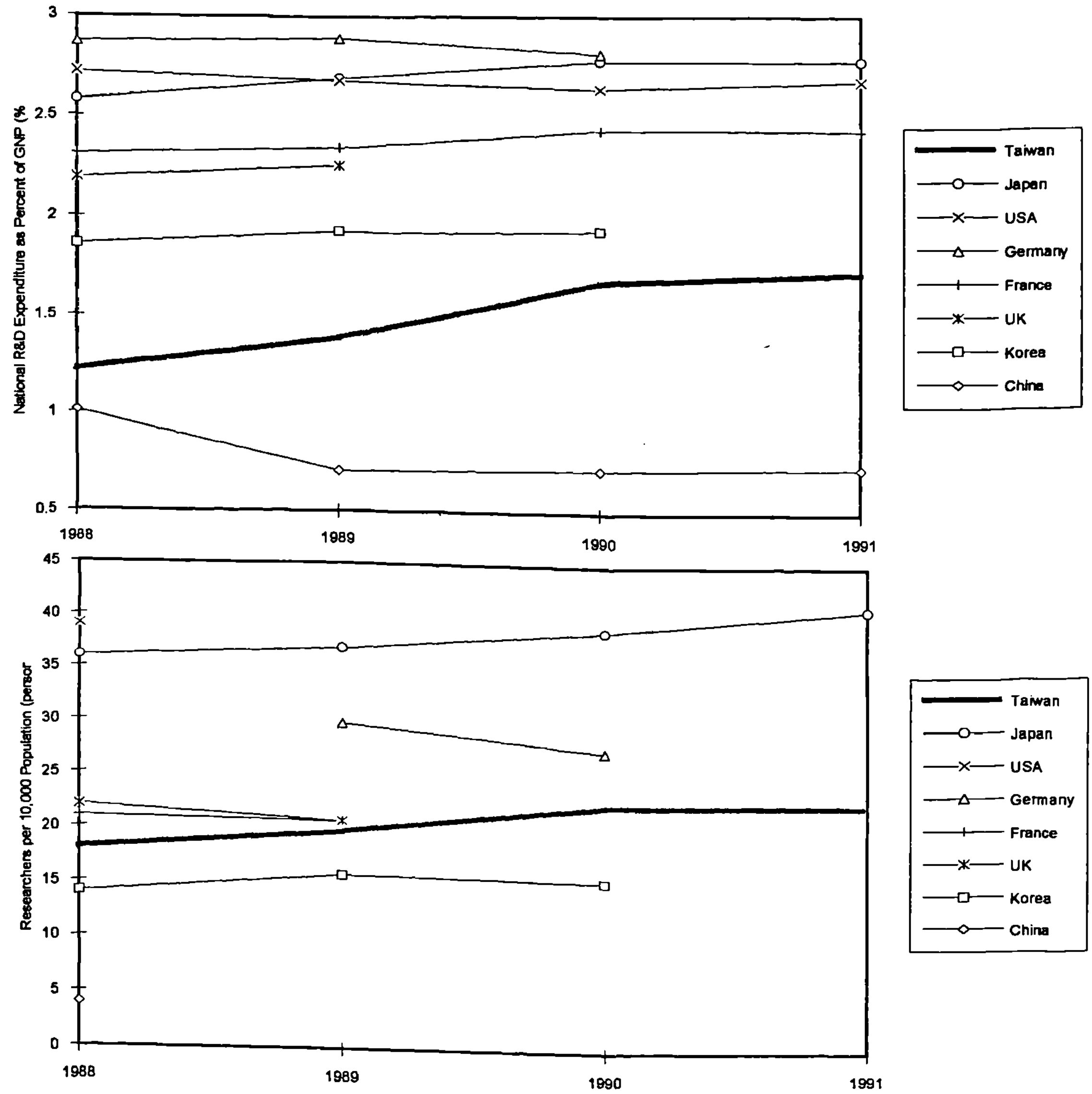
Source: Domestic & Foreign Express Report of Economic Statistics Indicators, No.115, July, 1993, Department of Statistics, Ministry of Economic Affairs.

the national focus of Taiwan's R&D, in which down-stream development applications are far more important than up-stream basic researches (also see Figure 4.6). This also explains why Taiwan has been highly competent in product developments rather than in scientific researches. Figure 4.7 provides a more in-depth view of the allocation of Taiwan's national R&D expenditure. The core of the national R&D system is based on the close co-operation of universities/colleges, research institutes, and industries, in which they play exclusive roles. The universities/colleges take charge of basic researches, while the research institutes responsible for most applied researches and industries implement these scientific researches into product applications. Universities/colleges bridge the scientific results from basic researches to applied researches; research institutes transfer the know-how from applied researches to experimental developments. Down-stream industries pick up the research results and produce real-world applications.

New Product Development and Domestic Competition

Backed by the national R&D system discussed above, Taiwanese firms have been highly proficient in product innovation. Especially in recent years when technology-intensive industries steadily increased their impact upon national production, the potential of NPD capability of Taiwanese firms has gradually been recognized. In 12 years, labour-intensive productions as a percentage of national productions decreased from 43.5% in 1982 to 32.3% in 1993, while technology-intensive productions increased from 19.6% to 31.7% in the same period (Figure 4.8). Taiwan export records show an even more dramatic change. In 1982 labour-intensive products accounted for 50.3% of total Taiwanese exports; in 1993 the ratio was reduced to 30.8%. In the meantime, the export of technology-intensive products increased from 29.1% to 44.9% (Figure 4.9). In 1994, Taiwan dominated 15 product categories in the global market, of which about one third are technology-intensive products. Moreover, Taiwan out-performs most countries in the world in terms of information products; by 1994 Taiwan was the fourth biggest producer of information products in the world, with small differences lagging behind the US, Japan, and Germany. For some product categories (e.g., Scanners, Modems, Notebook Computers) Taiwanese firms have already taken the lead in terms of technological competency. The

Figure 4.4 Comparison of R&D Input in Major Countries

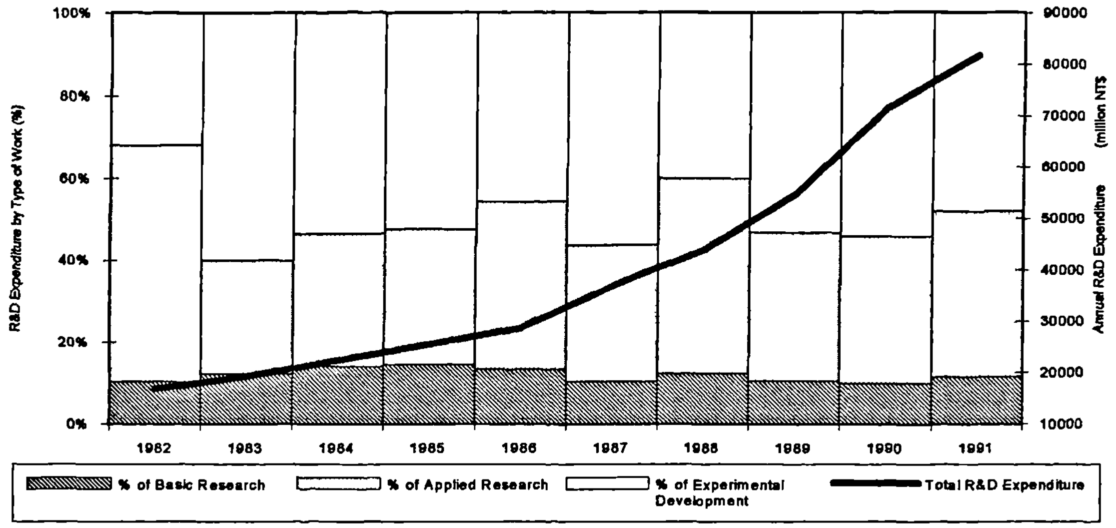


Source: Indicators of Science and Technology, Republic of China, 1993.

previous image of Taiwanese firms as low-end imitators has been changed to that of high-tech innovators.

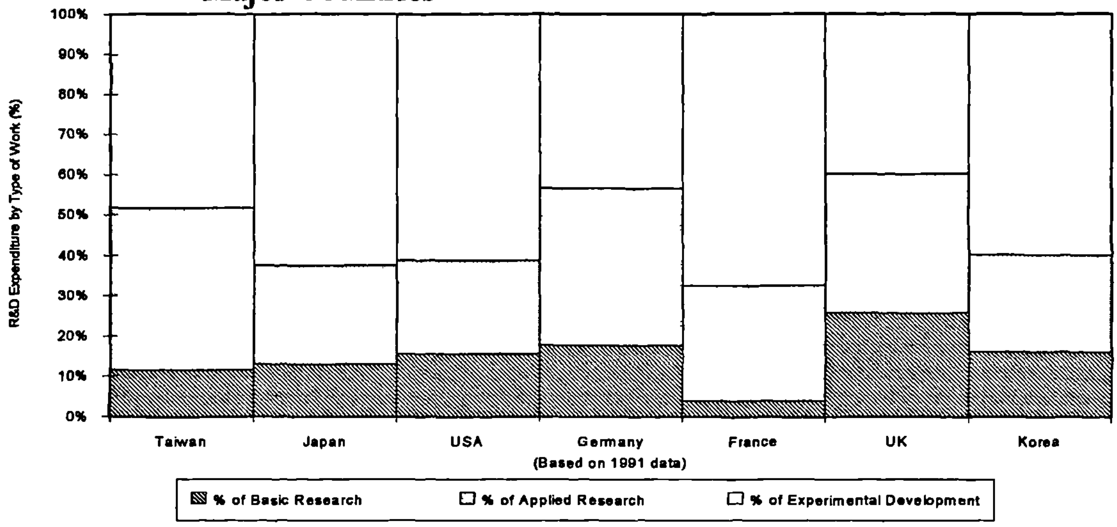
However, a closer look at Taiwanese competence in product development reveals two phenomena distinguishing Taiwanese firms from others. First, a wide range of approaches for product innovation exists in one single area, Taiwan. The historical influences from China, Japan, and America and the fast economic growth over the last 50 years have enabled Taiwan to become a pluralistic economic system. Business culture in Taiwanese firms is a combination of ancient and modern, east and west. As a result, NPD approaches in Taiwanese firms are also highly

Figure 4.5 National R&D Expenditure by Type of Work



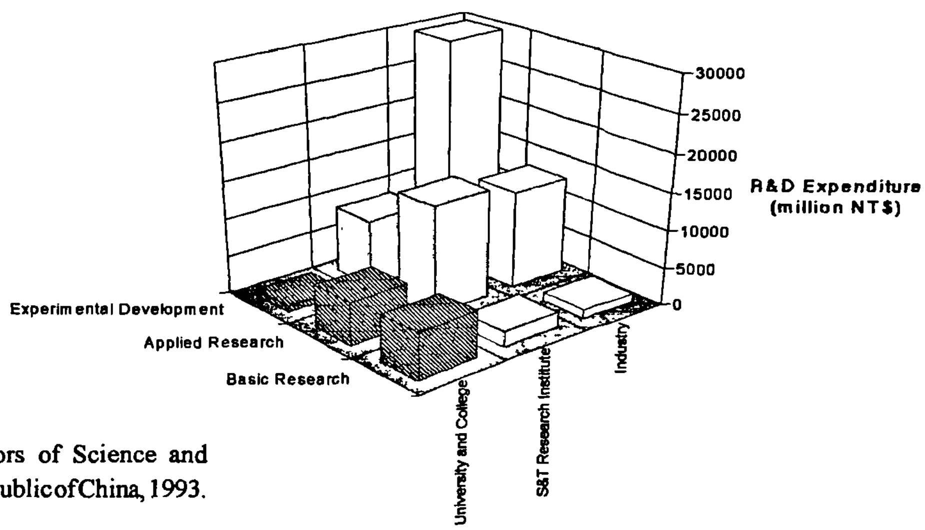
Source: Indicators of Science and Technology, Republic of China, 1993.

Figure 4.6 Comparison of R&D Expenditure by Type of Work in Major Countries



Source: Indicators of Science and Technology, Republic of China, 1993.

Figure 4.7 Allocation of National R&D Expenditure



Source: Indicators of Science and Technology, Republic of China, 1993.

diversified. NPD activities are found across a range of products: from traditional agricultural products to highly industrialized products, from very low cost imitations and incremental innovations to the most radical breakthroughs. This provides a great opportunity for the current research to study a wide range of R&D activities in a single area.

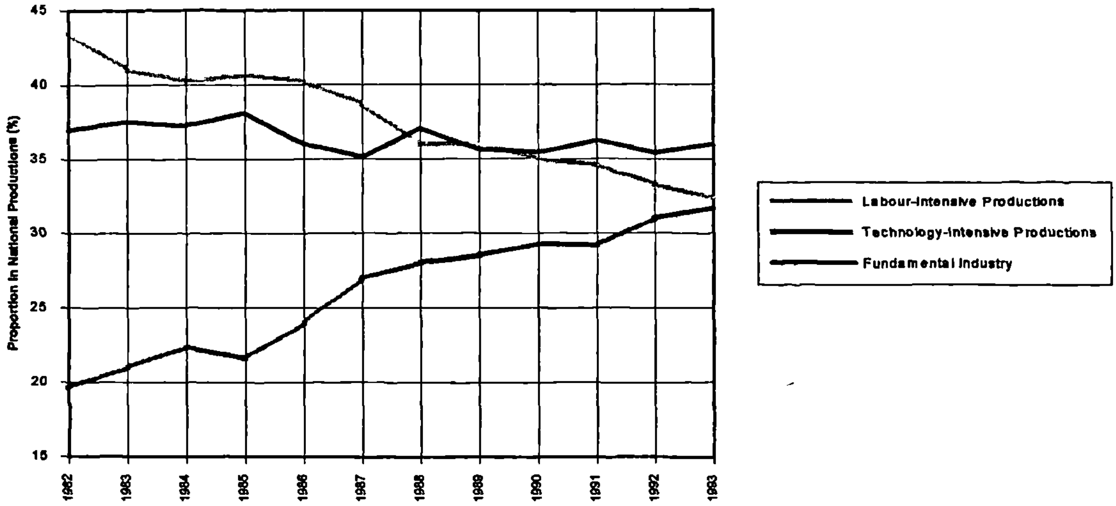
Secondly, compared to the figures of some western studies, NPD failure rates of Taiwanese firms were reported as surprisingly low. For example, Booz, Allen, and Hamilton (1982) suggested a 75% failure rate of American new product developments, while failure rates in Taiwanese firms were around 19% to 30% (Lin, 1988). Two factors may explain the difference. Firstly, Taiwanese firms tend to select relatively low risk incremental developments. These innovations are launched into markets that are often tried and tested and, therefore, have a higher probability of success. The second factor that contributes to the low NPD failure rate is related to the relatively high corporate shake-out rates in Taiwan. Accounts of failed NPD stories are usually concealed at the time of liquidation of poorly performing companies and, therefore, the true figure for NPD failure rate in Taiwan is often distorted.

One of the distinctive features of Taiwan's economy is its vitality, in which poor performers are quickly replaced by new entrepreneurs. In 1992 14,972 firms (3.64%) were shaken-out from Taiwan's domestic market. Meanwhile, 56,805 ambitious new firms entered the pool, accounting for 15.36% of total company population (Figure 4.10). However, on average about 16% to 20% of this fresh blood will disappear after the first year of operation (Economic Daily News, 14, July, 1994). In some high-tech industries the shake-out rate has been even more dramatic. For example, in 1992 there were more than 100 Notebook Computer producers operating in Taiwan; in 1994 only 20 remained. As a result, the researcher found difficulty in gaining access to the failed NPD cases because most companies with poor R&D records had already left the marketplace.

4.5.3 Sampling Frame

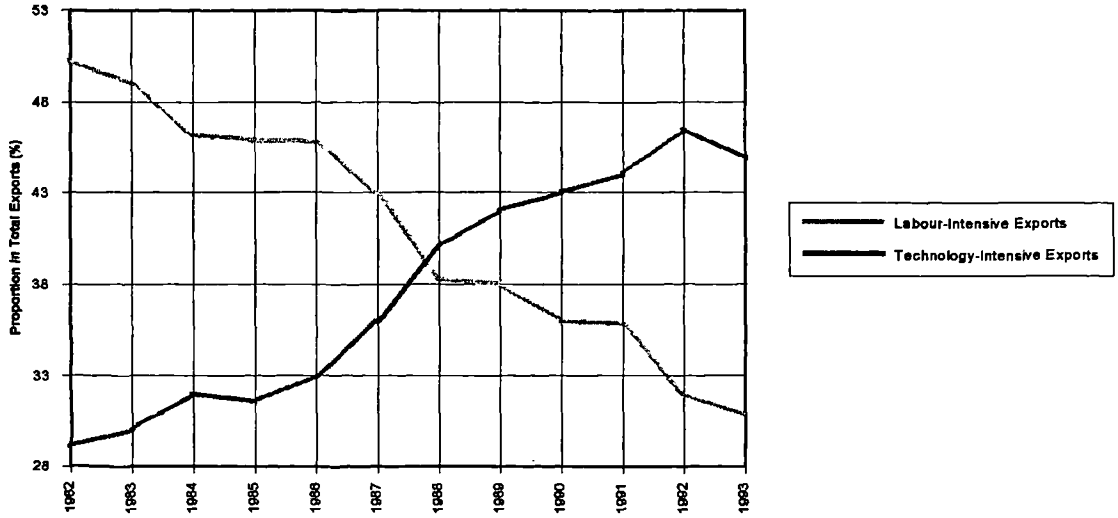
The current study selected Taiwan as the focal area for conducting fieldwork. In addition, to focus the research scope, only consumer products are considered. As this study uses a

Figure 4.8 National Production Movements in Taiwan



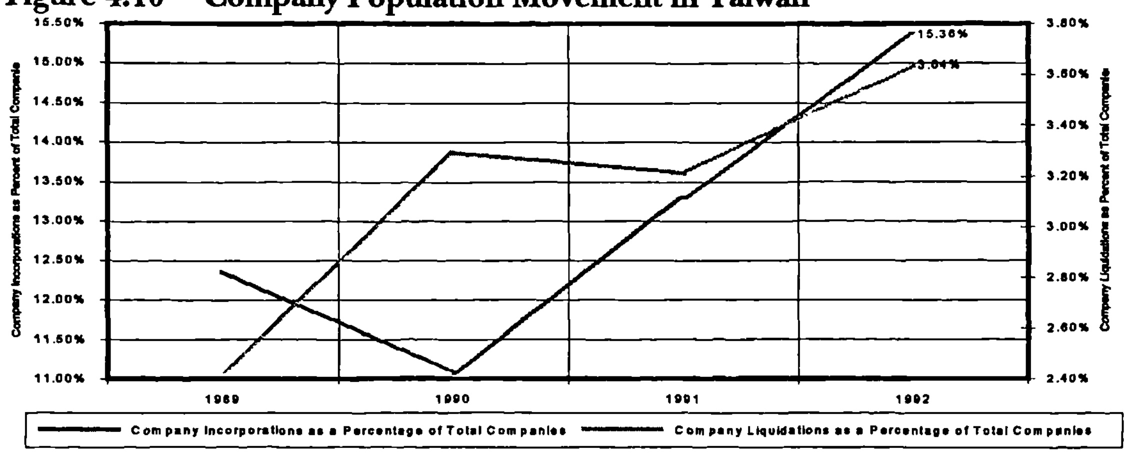
Source: Industrial Development Bureau, Ministry of Economic Affairs, R.O.C., 1994.

Figure 4.9 Export Movements in Taiwan



Source: Industrial Development Bureau, Ministry of Economic Affairs, R.O.C., 1994.

Figure 4.10 Company Population Movement in Taiwan



Source: Domestic & Foreign Express Report of Economic Statistics Indicators, No.115, July, 1993, Department of Statistics, Ministry of Economic Affairs, R.O.C.

contingency model to examine product innovation activities, the heterogeneity of NPD cases is highly necessary. The researcher appreciates that there were other studies investigating industrial product innovation; however, the major concern in these studies was not aimed at comparing NPD managerial behaviour between different project types. There are two key reasons for choosing only consumer products. First, it is difficult to define an industrial product because it is not in the final form of a "product"; it can be a complete product in itself, but merely a component of another product. Secondly, industrial products produced by different suppliers are often very similar as they must comply with certain industrial standards. Therefore there is little originality in most "new" industrial products. The sampling frame for the current research therefore is defined as a population that has the following attributes:

(1) The basic unit of the research cases is the complete NPD project, i.e., it had a complete NPD process from strategy development to new product commercialisation. Dead projects or prototypes of a project are not considered as the focal objects of the current research.

(2) The end product of the NPD is a consumer product.

(3) The developers of the new products are those companies who operate in Taiwan, regardless of whether they are local companies or the subsidiaries of foreign firms.

(4) The developers of the new products must have their own R&D as well as manufacturing facilities so as to fulfil the entire NPD process defined by the current study. Thus, service industries were excluded from the current research design.

4.5.4 Sampling Design

The current study uses a random sampling design for collecting research data. Such random sampling is achieved by a two-stage process; the first stage identifies the focal companies for the study and the second stage selects NPD projects for data collection. At the first stage, based on the above sampling frame, the focal firms were defined as having the following attributes:

(1) they develop and produce consumer goods;

(2) they have an annual turnover of US$20 million or above;

(3) they have established R&D functions in the organisation;

(4) they own manufacturing facilities.

Three hundred and twenty-six firms listed in "The Top 1000 Manufacturers in Taiwan" (Common Wealth Report, June, 1993: 95-182) were identified as satisfying the above criteria. Each company was labelled with an identification number. By using a random table generated by a computer programme written by the researcher, sixty firms were chosen from the list. There was no statistical reason to choose the number of "60" firms for sampling. It was simply a judgement by the researcher that this was the maximum number possible for the researcher to do the fieldwork in a limited time with limited budget. After initial contacts with the R&D executive of each firm, fifty-three firms responded positively to the request for providing information for the research, which represent 88.33% of the response rate and 16.26% of the total sampling frame. As suggested by Chatfield (1991: 11), the representativeness of a sample is not decided totally by the percentage of the sample to its population. More important, it is the sampling process that matters. In-depth interviews were arranged with the R&D executive of each firm.

At the second stage, the NPD cases for the research were randomly selected through the interviews. During each interview, the primary informant (who was typically the R&D executive) was requested to provide a list of NPD projects that had been carried out and were eventually marketed by the company in the previous five years. Similar to the first stage sampling process, each NPD was labelled with an identification number and a random table generated by the computer programme was used to select a NPD project from the list. The number of cases selected for each firm was dependent upon the available interview time given by the firm. The individuals who had the best knowledge about the projects were nominated by the primary informant and were requested to participate in the study. Subsequent interviews were arranged with these individuals.

4.5.5 *Efforts to Increase the Response Rate*

A number of studies have provided techniques to improve the response rates of quantitative researches. Especially for mail surveys, the utilisation of techniques to increase response rate was regarded as the norm in conducting this type of research. Although the current study does not use the mail survey for acquiring research data, these studies provided insights into the current research design. Jobber (1990) presented a well organized literature review that focused on techniques for maximizing response rates in industrial mail surveys. He categorized these techniques into three basic types:

(1) Preliminary Notification Techniques, e.g., prior notification letters, commitment post cards, telephone messages.

(2) Concurrent Techniques, e.g., monetary incentives, type of postage, anonymity.

(3) Follow-up Techniques, e.g., follow-up letters and questionnaires.

He concluded that some of the concurrent and the follow-up techniques show a higher effectiveness of improving survey response rates. Another important study by Jobber and Saunders (1989) provided a non-linear model for predicting the response rates of industrial mail survey. They concluded that three techniques are highly effective in increasing response rates, i.e., (1) number of contacts, (2) incentives, and (3) anonymity. By following their guidelines, the current study increased the number of contacts, provided special incentives, and used a personal-contact strategy to increase response rate.

The current study used the strategy of arranging all interviews through direct and personal contacts with the R&D members of the firms without circulating the research request through the whole company. Moreover, the researcher had agreements with all the interviewees that their names and individual project details would not be exposed to the public or be published in the final research report. The researcher believes that such a private-contact design can avoid the complexity of organisational politics on the one hand and reduce possible resistance to providing sensitive data, such as on product innovation, on the other hand.

The R&D executives were identified by telephone enquiries to the headquarters of each firm. The names, addresses, and extension numbers of R&D executives were acquired through this initial contact. This information was double checked by secondary data where available. An invitation letter as well as an announcement of a software gift was sent to these potential informants, requesting an in-depth interview. Several phone calls were made one week later to confirm the willingness of each potential informant to participate. If the response was positive, an initial interview was therefore arranged.

Several special incentives were provided directly to the informants, rather than to the companies. First, a comprehensive literature review of project management tools/techniques (written in the Chinese language by the researcher) was presented to informants who requested it. Secondly, the researcher promised to provide a concise copy of the research report to each informant. Finally, a computer software called WINNOVATOR (i.e., WINNO V.1.0 for DOS and Windows) developed by the researcher was presented to all informants at the first contact (see Appendix I). This is a project screening system based on the quantitative models (i.e., discriminant functions) developed by previous academic works. The users answer a series of questions with 9-point Likert-type scales and the system calculates the score of each performance predictor and compares the results with the empirical conclusions from these previous researches. The system therefore can appraise the possible commercial performance of any project idea in a prior hoc manner and provide managerial suggestions for the project managers.

Such a software incentive perhaps was the major reason that the current study obtained a respectable response rate, i.e., 88.33%. Many informants honestly stated in the interviews that their participation in this study was largely because of this software.

4.5.6 Data Collection

The fieldwork of this research was conducted during 1993 and 1994. Thus, the sample projects resulted in products launched between 1988 and 1993. Moreover, as the sample design is based on the representative sampling approach, both successful and failed cases of new product launch were acquired. The sample consists of 112 NPD cases from some 53 firms operating in the consumer goods industries. Among these samples, 99 cases are successful product innovations and 13 are uncertain or failed ones. The uneven counts of successes and failures to some extent represent the nature of the economic environment for Taiwanese firms (see Section 4.5.2). On the one hand, firms with high NPD death rates were quickly shaken-out from the marketplace and, therefore, it is difficult to access the failed NPD cases. On the other, most NPD undertaken in Taiwan were not really radical innovations in terms of global competition; they often faced less uncertainty in both technology and market acceptability and therefore it was easier for them to succeed. As failed cases are relatively few, quantitative examination in the thesis will focus on only the successful cases. Nevertheless, an in-depth investigation of a few failed cases will be provided in Chapter Ten, using the qualitative case study approach.

§4.6 Validating the Research Design

A research design acquires data that truly reflect the nature of the research domain and therefore validate the research. This can only be achieved by a well designed instrument, accurate data records, and a representative data set. The accuracy of research data records depends on the correctness of ***transformation and coding processes.*** Representative data sets can be acquired from an ***adequate sampling process.*** However, to assure the quality of research instruments requires more in-depth examination. Emory (1976: 109) highlighted four basic elements of good quality instrument design, i.e., (1) ***objectivity,*** (2) ***validity,*** (3) ***reliability,*** and (4) ***practicality.*** The following describes these extra efforts to validate the research design.

4.6.1 Objectivity

Objectivity is the extent to which the expression and measurement of an instrument are objective. Any user draws the same understanding of the instrument without being influenced by subjective judgements. The current study used exploratory investigation to test and improve the objectivity of instrument design. Vague or inaccurate wordings and measurements were removed at this initial stage, based on suggestions provided by interviewees. Furthermore, as the instrument was used along with the in-depth interviews, the researcher can help to clarify statements made by informants.

4.6.2 Validity

Validity is the extent to which an instrument truly reflects the intended concepts in the research. At least three types of validity need to be considered in any research design, i.e., (1) content validity, (2) concurrent validity, and (3) construct validity.

Content Validity

Content validity considers the representativeness of sampling design and the essence of the research instruments. As the current study adopted a random sampling approach, there is little doubt about the representativeness of the sample. The major consideration is the content validity of instrument design. A high validity of instrument design should be able to represent the essence of the research questions. The variables, or questions, stated in the instruments should be able to acquire the necessary information to answer the research questions. To do so, the current study employed several ways to assure its content validity.

First of all, the key variables that construct the current research framework were identified through a very broad, in-depth, and highly structured literature review, in an attempt to better describe the nature of the research questions. Ultimately, more than 350 journal articles and books were reviewed and organized in a highly structured way (see Chapter Two). This provided strong theoretical background for the instrument design. Secondly, several sets of well-recognized questionnaires for NPD research such as the NewProd questionnaire (Calantone and di Benedetto, 1990; Cooper, 1992) and the Calantone Questionnaire (Calantone, di Benedetto, and Divine, 1993) were studied to guide the questionnaire design for the current research. Thirdly, five R&D engineers from four Taiwanese firms (i.e., Yue Loong Group, YTM Group, Aten Corp., and Enlight Corp.) provided valuable help for the construction and wording of the initial questionnaire. This insured that the instrument design was acceptable from a practical point of view. Finally, the questionnaire used in the current study was tested, through a well-designed exploratory study. The content and wording of the questionnaire were further refined.

Concurrent Validity

Concurrent validity considers the predictive power of the research instrument. The most common technique to examine the concurrent validity of a research instrument is through the re-test procedure using the same instrument. Two or more informants are requested to answer the same set of questions concerning the same research object. If the correlation between the two (or more) pairs of answers is significantly high, concurrent validity is assured.

As time and the budget available imposed limitations on the author, only five NPD cases from the exploratory study were re-tested in the fieldwork. These five cases are: (1) AcerPower from Acer Corporation, (2) ModulePC from DFI Corporation, (3) Elite 486U from Elite Corporation, (4) Elite 486sx from Elite Corporation, and (5) KDM1788 from Sampotek Corporation. Correlations as well as the paired-sample t-Tests were employed to examine the concurrent validity of the instrument used in the current research. As stated in Table 4.3, both sets of answers were highly correlated, with correlation coefficients ranging from 0.8364 to 0.8840 and meanwhile all significant in $P < 0.001$ level. In addition to the Correlation results, the paired-sample t-Tests also showed that there was no significant difference between the two sets of answers (in terms of $P > 0.05$ level). The concurrent validity of the instrument design was therefore confirmed.

Construct Validity

Construct validity examines whether the variables in an instrument are well-structured, effectively representing the nature of the research domain. The major approach to examining construct validity is through statistical techniques such as the Kaiser-Meyer-Olkin Measure of Sampling Adequacy, the Bartlett Test of Sphericity, and the communality calculation of Factor Analysis. The current study used all these techniques to assure construct validity.

The twenty variables that constructed the internal contingent factors were examined in terms of construct validity. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (MSA) and the Bartlett Test of Sphericity were calculated in an attempt to explore the possible construct underlying these twenty variables. The resultant MSA (0.75) and the significance of Bartlett Test ($P < 0.001$) suggest a highly stable instrument design. Moreover, Factor Analysis showed that the communalities of these twenty variables were large (ranged from 0.55 to 0.89), which assured that the factors extracted from Factor Analysis successfully represented the underlying construct of the original data sets. This means that the instrument design accurately reflected the nature of the research domain. The construct validity of the instrument design is also verified. For a more detailed description of the above validation procedures please refer to Chapter Five.

4.6.3 *Reliability*

Reliability is the extent to which repeat measurement of, for example, internal contingent variables, carried out by the same informant can produce similar or consistent results. Reliability is different from concurrent validity because the focus of examination is the reliability of the measurement, in which the same instrument is re-tested by the same informant and the results from both tests should be similar. Theoretically the most preferable way of testing the reliability of an instrument is through the test-retest procedures of the same instrument with the same informant at different points in time. However, practically, it is difficult to request the informants to take the same test at different time points. The "noise" caused by the testing environment and the characteristics of the informants can also distort the results of time-based reliability tests. An alternative way is through statistical techniques that examine the internal consistency of variables in the same data set. Several techniques have been developed for this purpose, e.g., the split-half technique, the item discrimination analysis, and the Cronbach Alpha test. The current study used the Cronbach Alpha test to examine the internal consistency of the current instrument design.

The internal consistency of instrument design was examined by using the (Cronbach Alpha) Reliability Test. Based on the twenty variables that describe NPD internal contingencies, the reliability test was conducted to assure the construct reliability of the factors produced by Factor Analysis. Five factors were identified through Factor Analysis. Cronbach Alpha was calculated to measure the internal consistency of each factor. The resultant Alpha values ranged from 0.5807 to 0.8757, suggesting the questionnaire is reliable. For a more detailed description of the above validation procedure please refer to Chapter Five.

4.6.4 *Practicality*

Practicality refers to the feasibility of implementing such a research design. This includes considerations of economy, convenience, and interpretability. For example, the larger the sample size, the better the normality of the research data sets; however, it also increases the difficulty of fulfilling the research caused by the limitation of available research resources (i.e., time and funding). The current study has carefully considered such issues in an attempt to achieve a balance between the feasibility and the quality of research design.

Table 4.3 Examination of Concurrent Validity of the Research Instrument Used in the Current Study

Correlation Analysis:		
Variables Used for Validation	**Correlation Coefficient**	**Significance (2-tail)**
Performance Measures (seven variables)	0.8364	$P < 0.001$
Internal Contingencies (twenty variables)	0.8650	$P < 0.001$
External Contingencies (four variables)	0.8840	$P < 0.001$
Paired Sample t-Test:		
Variables Used for Validation	**t-Value**	**Significance (2-tail)**
Performance Measures (seven variables)	-1.82	$P = 0.080$
Internal Contingencies (twenty variables)	1.50	$P = 0.137$
External Contingencies (four variables)	-0.93	$P = 0.374$

The paired data are extracted from five NPD cases that were investigated both in the exploratory study and in the fieldwork.

4.6.5 *Representativeness Considerations*

Representativeness of Sample Firms

ANOVA and χ^2 Tests were used to examine the representativeness of sample firms to the sampling frame. Four descriptive variables were considered for making the comparison, i.e., the annual turnover, company assets, registered capital, and the number of employees. Both ANOVA and χ^2 Tests showed that the sample firms in the current study adequately represented the sampling frame (Tables 4.4 and 4.5).

Non-response Problem

Only seven out of sixty firms (11.67%) refused to participate in the current study. As a result, the non-response problem, if any, is trivial. The non-response tests are therefore omitted. The major reason these companies did not participate in the current study was the unavailability of informants during the research period (57%). This included: (1) too busy to fit into his/her appointment list, (2) on holiday, (3) going abroad, and (4) during a period of organisational restructuring. Another reason was the unwillingness of firms to provide sensitive R&D information to outsiders.

4.6.6 Data Coding and Analysing

The current study took great care to insure the quality of digitising of research data acquired through fieldwork. The first step was to develop a computer database for inputting the data. This was done by using a database software called Approach from Lotus Corporation to generate data structure as well as input screens. This software allowed the researcher to design input screens that were highly similar to the original questionnaire, in which data were inputted by using mouse to point from the list boxes or scroll through the scroll bars under the Microsoft Windows operation environment. This was especially useful when some of the data type were verbal items extracted from the content analysis of qualitative statements. It was not necessary for the researcher to type these verbal items manually into records; rather, it was done simply by a mouse clicking. This provided a means to prevent data input from any typing mistake.

Quantitative data were inputted directly based on the interviewees' answers. Because the collection of data was through in-depth interview, there was no missing value in the questionnaires. Content analysis was used to quantify the qualitative information from interviewees' verbal statements. The basic technique was to list the statements of interviewees. For example, based on the interview structure (Appendix V. Part Two: 10), the researcher requested the interviewee to state any special arrangement by the company believed to be extremely useful in facilitating the project. The interviewee simply listed all the managerial arrangements that s/he believed to have significant impact on the project. These verbal items were therefore added and sorted as computer files. If there were items that described a similar situation or activity, they were combined and labelled with a common name.

The coding of information processing activities is worth mentioning. With reference to the instrument design, the current study uses an unique approach to record the complexity of NPD information processing. Information flows were mapped diagrammatically by drawing links between information sources, informants, communication channels, and information users. To digitise such qualitative information, these verbal items were categorized. For example, information sources were categorized into bounded (i.e., inside the company) or unbounded ones (i.e., acquired from outside the company). For each case, the number of a certain type of item (e.g., the

Table 4.4 Comparison of Characteristics between Sample Firms and the Sampling Frame (ANOVA)

Descriptive Variables	Sampling Design		F Value	Significance
	Samples	Population		
Annual Turnover (NT$000,000)	3787.6226 (5429.8697) n=53	3135.3810 (6248.6949) n=273	.5034	.4785
Company Assets (NT$000,000)	3460.2642 (5257.4756) n=53	2838.7731 (6605.9289) n=260	.4151	.5199
Registered Capital (NT$000,000)	1197.0377 (1926.0168) n=53	838.9853 (1847.5427) n=273	1.6441	.2007
Number of Employees (person)	860.1321 (1070.4724) n=53	818.7289 (1477.5602) n=273	.0377	.8461

Calculations are based on the data of fiscal year ended on 30 June, 1992.
Source: Common Wealth Report (1993), The Top 1000 Manufacturers in Taiwan, ***Common Wealth***, June, 95-182.

unbounded sources) that were used by the project was counted; the number of information flows identified by the interviewee was counted; the number of communication channels used was also counted. In this way the character of information flows of each information type for each case was recorded in quantitative form (i.e., frequencies). More detailed descriptions of these calculations are provided in the data analysis chapters (i.e., Chapter 6 and Chapter 7).

Furthermore, the categorization of qualitative data was double checked by using a duplicate-coding approach. Provided with a set of certain rules, a postgraduate student in marketing science reproduced the coding process (i.e., transferred qualitative data into quantitative data) for the research. The results from the second coding process were compared with the first set of results provided by the researcher. There was little inconsistency in the comparison. A minor modification of the data set was made based on the consensus between the postgraduate student and the researcher.

Finally, descriptive analyses were conducted to explore the quality of the data set. The means, standard deviations, data ranges, frequencies, and distributions of all variables were computed in an attempt to provide a visual means to check the data input quality. The final data set was analysed using SPSS for Windows (ver.5.0) developed by SPSS Inc.

Table 4.5 Comparison of Characteristics between Sample Firms and the Sampling Frame (Chi-Square Tests)

Annual Turnover	less than NT$1000 Millions	NT$1000M to NT$1499M	NT$1500M to NT$1999M	NT$2000M or higher	Total
Population	91 (33.3%)	54 (19.8%)	27 (9.9%)	101 (37.0%)	273 (83.7%)
Samples	19 (35.8%)	7 (13.2%)	3 (5.7%)	24 (45.3%)	53 (16.3%)
Total	110 (33.7%)	61 (18.7%)	30 (9.2%)	125 (38.3%)	326 (100.0%)

Chi-Square=2.76566; Degree of Freedom=3; P=.42918 (not significant)

Company Assets	less than NT$1000 Millions	NT$1000M to NT$1999M	NT$2000M to NT$2999M	NT$3000M or higher	Total
Population	107 (41.2%)	69 (26.5%)	30 (11.5%)	54 (20.8%)	260 (83.1%)
Samples	18 (34.0%)	10 (18.9%)	9 (17.0%)	16 (30.2%)	53 (16.9%)
Total	125 (39.9%)	79 (25.2%)	39 (12.5%)	70 (22.4%)	313 (100.0%)

Chi-Square=4.38975; Degree of Freedom=3; P=.22234 (not significant)

Registered Capital	less than NT$200 Millions	NT$200M to NT$399M	NT$400M to NT$599M	NT$600M or higher	Total
Population	98 (35.9%)	40 (14.7%)	43 (15.8%)	92 (33.7%)	273 (83.7%)
Samples	15 (28.3%)	5 (9.4%)	8 (15.1%)	25 (47.2%)	53 (16.3%)
Total	113 (34.7%)	45 (13.8%)	51 (15.6%)	117 (35.9%)	326 (100.0%)

Chi-Square=3.87030; Degree of Freedom=3; P=.27582 (not significant)

Number of Employees	less than 200	200 to 399	400 to 599	600 or higher	Total
Population	50 (18.3%)	86 (31.5%)	43 (15.8%)	94 (34.4%)	273 (83.7%)
Samples	10 (18.9%)	10 (18.9%)	8 (15.1%)	25 (47.2%)	53 (16.3%)
Total	60 (18.4%)	96 (29.4%)	51 (15.6%)	119 (36.5%)	326 (100.0%)

Chi-Square=4.39803; Degree of Freedom=3; P=.22157 (not significant)

Calculations are based on the data of fiscal year ended on 30 June, 1992.
Source: Common Wealth Report (1993), The Top 1000 Manufacturers in Taiwan, ***Common Wealth***, June, 95-182.

§4.7 Limitations of the Current Research Design

Although a great deal of effort was made to insure the quality of the current research design, there are limitations owing to the constraint of available research resources. Any interpretation or generalisation of findings from the current study is subject to the following limitations. There are two major sources constraining the generalisation of any empirical researches, i.e., (1) the limitation caused by the research approach, and (2) the limitation caused by the sampling design.

4.7.1 Limitation Caused by the Research Approach

The major concern here is the use of a *post hoc* research design. Informants were requested to recall NPD details that occurred during the previous five years. Limits to memory recall mean that project information provided by informants might be distorted. Furthermore, only significant information flows can be recorded. Nevertheless, this is the common limitation of any *post hoc* research.

4.7.2 Limitations Caused by the Sampling Design

The Population

The results from the current research can only be applied to Taiwanese firms that show the following characteristics:

(1) they develop and produce consumer goods;
(2) they have an annual turnover of US$20 million or above;
(3) they have established R&D functions in the organisation;
(4) they own manufacturing facilities.

Any generalisation of the research results to other populations would be premature. However, the findings do provide insights into the different NPD information/knowledge management behaviour that can occur across different NPD contingent situations.

Possible Sampling Errors

Sampling errors relate to the sampling design itself. Such bias may occur because of the under- or over-representation of particular types of cases in the sample compared with the population as a whole. Although the current study used the random sampling technique to access the research sample, there was a potential drawback embedded at the second stage of the sampling process. The primary informant of each interview was requested to list as many as possible of the NPD cases conducted by the company in the previous five years. The sample was therefore randomly selected from the NPD list. The quality of such a list, based on the memory of historical events by the primary informant, was beyond the control of the researcer. Possibly the list merely represented the informant's preferences in selecting NPD cases rather than the full picture.

Possible Non-Sampling Errors

Non-sampling errors arise in the implementation of the sampling design. As the research data were provided by people, response errors due to informants giving the "wrong" answer, intentionally or unintentionally can occur. Non-response errors may also occur when the view of non-respondents is distinct from others, and the number of non-respondents is large enough to outweigh the common view drawn from respondents. However, as the current study achieved a high 88.33% response rate, this problem was minimised. Other possible non-sampling errors such as processing errors or interviewer errors were also considered. As a great deal of effort was made to deal with these possible situations (see Section 4.6), it is reasonable to expect that these potential non-sampling errors were minimised as far as possible.

Notes

1. One of the basic assumptions in using parametric tests is the normal sampling distribution. According to the Central Limit Theorem, a couple of sampling distributions can be seen as normal distribution when the sample size is large enough and the sampling design is based on the representative sampling approach.

Take F Distribution as an example, F Distribution is constructed by 2 sets of Chi-Square sampling distribution acquired from 2 independent populations. When the degree of freedom is large enough, F Distribution can be treated as Normal Distribution, i.e.,

If $x_1, x_2, \ldots, x_n$ is a sequence of n independent and identically distributed random variables with $E(x_i) = \mu$ and $V(x_i) = \sigma$ (both finite) and $y = x_1 + x_2 + \ldots + x_n$, then

Given j sets of Chi-Square Sampling Distribution acquired from j sets of independent population

$$\chi_j^2 = \sum_{i=1}^{n} \left(\frac{x_i - \mu_i}{\sigma_i}\right)^2$$

$$f(\chi_j^2) = \frac{1}{\Gamma(\frac{n}{2})2^{n/2}} (\chi_j^2)^{\frac{n}{2}-1} e^{-\frac{\chi_j^2}{2}}$$

F statistics are calculated based on two given Chi-Square Sampling Distributions with v_1 and v_2 degrees of freedom

$$F = \frac{\chi_1^2 / v_1}{\chi_2^2 / v_2}; F(\alpha; v_2, v_1) = \frac{1}{F(1-\alpha; v_1, v_2)}$$

$$f(F) = \frac{\Gamma(\frac{v_1+v_2}{2})}{\Gamma(\frac{v_1}{2})\Gamma(\frac{v_2}{2})} \left(\frac{v_1}{v_2}\right)^{\frac{v_1}{2}} F^{\frac{v_1}{2}-1} \left[1 + \frac{v_1}{v_2} F\right]^{-\frac{1}{2}(v_1+v_2)}$$

When the sample size is large enough (i.e., has a large degree of freedom), both Chi-Square Distribution and F Distribution are approaching Normal Distribution

$$\lim_{n \to \infty} f(\chi_j^2) = N(\chi_j^2; n, 2n)$$

$$\lim_{v_1 = 1; v_2 \to \infty} f(\sqrt{F}) = N(\alpha; 1, \infty)$$

There are certain techniques in experimental design that are aimed at deciding the sample size for statistical analysis. However, in practice, a sample size larger than 20 (Chatfield, 1991) or 30 (Roscoe, 1975) with a good sampling design is sufficient for most statistical purposes.

Chapter Five

Sample Profiles and The Underlying Structure of NPD Situations/Conditions

5

This chapter provides a preliminary examination of research data in an attempt to reveal the nature of the sample used in the current study, and to investigate the situations/conditions in which NPD takes place. Profiles of companies, projects, and interviewees who participated in this study are presented. Meanwhile, the performance measures used in the current study are employed to divide the research sample into successful and failed cases. This is done by cross validating both the qualitative and quantitative measures of new product performance provided by the interviewees. In addition, as Chapter Three argued, the underlying structure of NPD situations/conditions is often highly complex and it cannot to be described by only one or two variables. This Chapter investigates the nature of internal and external NPD environments to identify possible patterns of contingent situations during product innovation. Cluster analyses are also conducted to classify sample cases based on these external and internal contingent factors. For internal NPD contingent factors, four types of NPD are identified, namely: (1) the Easy-to-Produce Radicals, (2) the Hard-to-Produce Radicals, (3) the Untried Incrementals, and (4) the Tried and Tested Incrementals. For external NPD contingent factors, three situations of market situations/conditions are found, i.e., (1) the turbulent situation, (2) the declining situation, and (3) the stable situation.

5 Sample Profiles and The Underlying Structure of NPD Situations/Conditions

§5.1 Introduction

This chapter describes the nature of the sample and data used in the current study. The definition of a valid sample for the study is a new product development project developed and commercialized by the sample firms in the last five years. One hundred and twelve NPD cases from 53 firms were acquired, 99 successful and 13 uncertain or failed. Profiles of sample companies, projects, and interviewees participating in this study were presented in Section 5.2. Section 5.3 divides the research sample into successful and failed/uncertain categories based on both subjective judgements and detailed performance ratings. A cross validation of both measures is provided to assure the classification of cases is accurate. Section 5.4 investigates the nature of NPD dynamics, in an attempt to differentiate the underlying structure of NPD situations/conditions. Twenty five contingent variables are examined to extract possible patterns of contingent situations during product innovation. These variables are divided into two groups; twenty of them represent the internal NPD environment (i.e., resources, the firm, the project) and five of them describe the situations/conditions of the incumbent marketplace. Factor Analysis is employed to extract possible contingent patterns from the complexity. Section 5.5 further uses Cluster analysis to categorize NPD cases based on these NPD contingent situations/conditions. A validation of such a classification is provided using Discriminant techniques. Section 5.6 presents a preliminary comparison of sample cases, based on their different contingent situations/conditions.

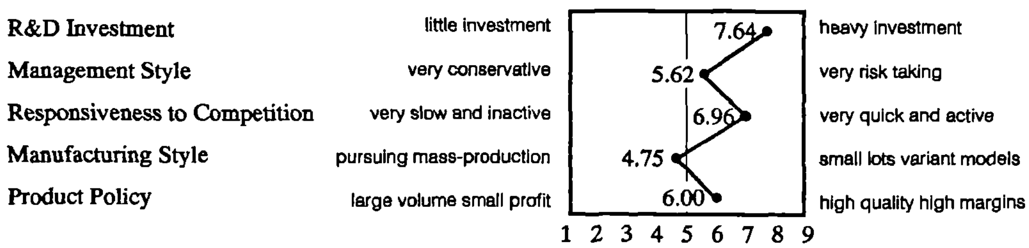
§5.2 Sample Profiles

5.2.1 The Sample Companies

Table 5.1 Company Profiles in the Current Study

Company Profiles	Average
Years since the company was established:	17.60
Number of new product developments in the last 5 years:	67.98
Percentage of technological success:	83%
Percentage of successful new product launch:	74%
New product contribution to annual turnover:	73%
R&D expenditure as a percentage of annual turnover:	9%

Strategic Profiles



Fifty three firms participated in the current study. As the current study imposed specific criteria for selecting these sample firms, the resultant sample does not represent all Taiwanese firms. Rather, they are firms with the following characteristics:

(1) they develop and produce consumer goods;

(2) they have an annual turnover of US$20 million or above;

(3) they have established R&D functions;

(4) they own manufacturing facilities.

In other words, compared to other Taiwanese firms, they are the larger companies (i.e., at least the top 870th according to the 1993 ranking list*), and they invest more resources in R&D. Table 5.1 shows the profiles of these sample firms. Not surprisingly, the sample firms have a higher ratio of R&D expenditure over annual turnover (9%) than the national average (1.7%). They tend to invest heavily in R&D activities (mean=7.64; 9-point Likert-type scales); they also

* Common Wealth Report (1993), The Top 1000 Manufacturers in Taiwan, Common Wealth, June, 95-182. The 870th firm in the list had a turnover of about US$20 million.

tend to respond more quickly to competition raised from both the market and technology (mean=5.96; 9-point Likert-type scales). However, the number of years they have been established (18 years) is not significantly different from the national average. For each firm the number of new product development projects conducted in the five years prior to this study is about 68. About 83% of these projects achieved technological success and actually reached the marketplace. For these commercialized NPD, the success rate was about 74%, which is consistent with the findings of previous surveys looking into Taiwanese firms (e.g., Lin, 1988). These successful new products have contributed about 73% to the average annual turnover. This also confirms western findings that used the same calculation basis. For example, Bonnet (1986) reported that the percentage of sales revenue accounted for by products introduced in the last five years was 55% to 90%.

5.2.2 The Sample Projects

One hundred and twelve cases were acquired for the current study. Table 5.2 presents the profiles of these samples. As these samples were acquired based on the random sampling design, the number of cases provided by the firms and the number of informants contributing to a case were not predefined. On average, each sample firm provided two cases for the current study (mean = 2.113). For each case, at least one informant participated in the interview and answered the research questionnaire (mean = 1.232). Where two or more informants participated, project information was based on a consensus of all informants. Considering the balance between sample size and the available time and budget for the fieldwork, the current study did not intend to conduct multiple interviews with different individuals about the same case.

In general about 10 people formed a project team; the tenure of the team would last about 15 months. During the development cycle time, about NT$28 million (i.e., about US$1.08 million) were spent for each project. The average PLC (product life cycle) of the new product expected by the informants is about five years. Among these projects, the ODM/OEMs (Original Designer and Manufacturer/Original Equipment Manufacturer) account for about 5.3% and the imitations of, or minor improvements to, existing products account for about 5.4%. Most of

Table 5.2 Sample Profiles in the Current Study

Average Team Size (persons):			10.21
Average Project Duration (months):			15.37
Anticipated Product Life Cycle (months):			60.51
Average Project Costs (NT$000):			27,774.71
Project Type:	ODM/OEM	7	(6.3%)
	Imitation	5	(4.5%)
	Licensed from other company	3	(2.7%)
	Minor improvement	1	(0.9%)
	other R&D	96	(85.7%)
Product Type:	Consumables	17	(15.2%)
	Durables	95	(84.8%)
Related Industry:	Information (Hardware)	46	(41.1%)
	Information (Software)	14	(12.5%)
	Electronic	14	(12.5%)
	Food	14	(12.5%)
	Mechanical	7	(6.3%)
	Sports Goods	5	(4.5%)
	Others	12	(10.7%)
How many cases per firm used in the current study?	One case	11	(20.8%)
	Two cases	26	(49.1%)
	Three cases	15	(28.3%)
	Four cases	1	(1.9%)
How many informants per case during interviews?	One informant	88	(78.6%)
	Two informants	22	(19.6%)
	Three informants	2	(1.8%)

the resultant products are consumer durables (84.8%). The majority of these new products are information products (53.6% including hardware and software). This reflects the current industrial trend of product innovation in Taiwan.

5.2.3 The Interviewees

For each sample case, at least one informant from the sample company provided necessary data. The major informants were identified during the interviews as they had the most direct involvement in the NPD case. Table 5.3 provides a background description of these key informants. On average, these informants were about 37 years old, with 13 years of total working experience, and had been with the current company for 8 years. The majority of the informants were R&D managers (55.4%), while the CEO/Vice Presidents giving information accounted for

Table 5.3 Profiles of the Major Informants

Average Age (years):			37.14
Average Tenure in the Current Company (years):			7.65
Average Working Experiences (years):			12.33
Education:	Postgraduate Degrees	44	(39.3%)
	Undergraduate Degrees	49	(43.8%)
	Diploma (polytechnic college)	13	(11.6%)
	others	6	(5.4%)
Position:	CEO/Vice Presidents	35	(31.2%)
	R&D Manager	62	(55.4%)
	Senior Engineer	15	(13.4%)

about 31.2% of the total sample. Most informants had good educational background; among them, 83.1% held at least an undergraduate degree, and 39.3% held a M.Sc. or Ph.D. degree.

§5.3 Successful versus Failed Projects

Two approaches are used for measuring performance and to differentiate successful projects from unsuccessful ones. The first approach is the case informant's subjective judgement of overall project success or failure (representing the judgement of the company). Such subjective judgements provide this breakdown of the sample: nine failed cases, ninety-nine successful cases, and four cases about which firms are uncertain of success. The second approach is also based on subjective but more detailed assessment on the fulfilment of seven NPD strategic goals by the new product, three of which are financial, and the other four non-financial (see Table 5.4). For each strategic goal, informants were requested to rate both the perceived importance (weight) of the goal and the performance of the new product in achieving it; both are measured by 9-point Likert-type scales. In cases having two or more informants, the assessment of NPD performance was based on the consensus of all informants. The final score of project performance is therefore calculated by aggregating the score and weight of each performance indicator.

Both performance measures clearly differentiate successful NPD projects from failures or those at risk. Moreover, the results of such differentiation from both measures show quite a consistent pattern of project success or failure. ANOVA and Discriminant Analysis are employed to make a cross-reference of both measures (Table 5.4). The success group (mean=8.0404) out-

Table 5.4 Comparison of Subjective Judgements and Performance Ratings in Determining Project Success or Failure

Detailed Performance Ratings	Judgement of Overall Performance: Failures & the Under Risks (n=13)	Judgement of Overall Performance: Successful Projects (n=99)	F	Significance
Sales	3.0000 (1.5811)	8.1313 (1.1308)	214.2964	P<0.001
Market Share	2.0769 (1.1875)	7.3838 (1.8828)	97.7089	P<0.001
Profitability	3.7692 (2.2418)	8.2121 (1.1978)	124.1854	P<0.001
Opportunity for entering a new business	2.3846 (2.2188)	2.5556 (3.0945)	0.0370	NS
Opportunity for entering a new market	2.0769 (2.4987)	2.0303 (2.5732)	0.0038	NS
Learning experiences, know-how, and technology	5.3077 (2.8978)	4.8889 (3.5252)	0.1681	NS
Maintaining or improving leading image in the market	2.1538 (1.4632)	6.9394 (2.7621)	37.4328	P<0.001
Weighted and aggregated performance score	3.9981 (1.2225)	8.0404 (0.8410)	236.7398	P<0.001

performs the failure and at-risk group (mena=3.9981), with a significant level of P<0.0001. In other words, subjective judgement of project performance has been highly consistent with detailed measures of performance. Such a result increases the validity of performance measures used in the current study.

§5.4 External and Internal NPD Contingent Situations

External Contingent Variables: Five variables are selected to portray external NPD contingent situations. These variables include expected product life cycle (in months), predicted market growth (measured by 9-point Likert-type scales), estimated market demand (measured by 9-point Likert-type scales), intensity of price competition (measured by 9-point Likert-type scales), and existence of a strong competitor (measured by 9-point Likert-type scales).

Internal Contingent Variables: Twenty variables are employed to represent internal NPD contingent situations (all measured by 9-point Likert-type-type scales). These variables include: (i) the familiarity of the firm with the project (in terms of technology, key parts, marketing, and manufacturing), (ii) the extent of project novelty (in terms of technology, marketplace, and manufacturing), (iii) the extent of project complexity (in terms of technology, project management, and manufacturing), (iv) the commitment measures (in terms of budget and CEO support), (v) project initiation (in terms of market-pull or technology-push), (vi) the clearness of project definition (in terms of the marketplace, product specification, and technology), and (vii) the positioning of the new product (in terms of functionality, quality, and pricing strategy).

Factor Analysis is employed to identify possible dimensions underlying these variables. The Correlation Matrix of Component Analysis[1] shows a 0.75 of Kaiser-Meyer-Olkin Measure of Sampling Adequacy[2] and a significance of $P < 0.001$ of the Bartlett Test of Sphericity[3] which suggest the employment of Factor Analysis is highly appropriate (Table 5.5). Factor Analysis is implemented based on cutoff values of 1.0 for the eigenvalue and ±0.30 for the factor loading (Hair, Jr. et al., 1992: 239). As the rejection of the existence of any general factor is not expected, the orthogonal rotation procedure (QUARTIMAX) is used. The validity of using QUARTIMAX rotation solution is also assured according to the Thurstone Criteria (Thurstone, 1942: 335, 1947).

Both the QUARTIMAX Rotated Component Analysis[4] and the Scree Test[5] clearly identify five factors from the 20 contingent variables with a total 14.49 eigenvalue and 72.4% of variances explained (Table 5.6). All the final communalities[6] for each of the variables are above 0.55 and have an average of 0.72, suggesting that the factor solutions are strongly representative. The Reliability Test (Cronbach Alpha)[7] also shows high internal consistencies of each factor, ranging from 0.8757 to 0.5807 with a Q value of 129.73 ($P < 0.001$). All these statistical results suggest the five factors are robust and are appropriate in representing the nature of internal NPD contingent situations. These five factors are labelled as:

(1) superior product profile,
(2) company synergy and competence,
(3) manufacturing difficulty,
(4) project clarity, and
(5) product uniqueness.

Table 5.5 Component Analysis Correlation Matrix

	Project Situation	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
(1)	Familiar with Productionn Process																				
(2)	Familiar with Marketing	.34527*																			
(3)	Familiar with Technology	.52764*	.35148*																		
(4)	Novelty in Production Process	-.49144*	-.05276	-.19791*																	
(5)	Novelty in Market Place	-.1264	-.23986*	-.26212*	.31274*																
(6)	Novelty in Technology	-.11028	-.20999*	-.17785*	.43399*	.60197*															
(7)	Complexity in Production Process	-.35452*	-.03079	-.16134*	.63045*	.18125*	.21084*														
(8)	Complexity in Technology	-.18500*	-.33202*	-.34068*	.23208*	.57825*	.60974*	.36810*													
(9)	Complexity in Project Management	-.12942	-.28380*	-.22790*	.13641	.40419*	.46447*	.46591*	.55602*												
(10)	Available Core Technology	.44410*	.33254*	.47876*	-.07956	-.03507	.05971	-.35828*	-.20081*	-.36890*											
(11)	Available Key Parts	.31978*	.13500	.06429	-.30857*	.02074	-.08236	-.54005*	-.22122*	-.45689*	.57117*										
(12)	Budget Support	-.33963*	-.36894*	-.29214*	.51324*	.47187*	.56862*	.26893*	.48093*	.33065*	-.18644*	-.19188*									
(13)	CEO Support	-.28160*	-.40730*	-.29892*	.40114*	.50361*	.56104*	.20957*	.47207*	.41285*	-.21778*	-.18553*	.89651*								
(14)	Market Initiated Idea	-.01102	.05629	.01215	-.15898*	-.51308*	-.39033*	-.22860*	-.28631*	-.39715*	.09176	.10853	-.26912*	-.30645*							
(15)	Clear about Market Place	.02044	.29567*	.03489	.16618*	-.14567	-.05477	-.11397	-.21379*	-.42609*	.33163*	.22119*	-.03258	-.18435*	.36816*						
(16)	Clear about Product Specification	.29855*	.34858*	.28247*	.00629	-.09719	-.21374*	-.21345*	-.31079*	-.48536*	.44301*	.27373*	-.19796*	-.20340*	.14554	.34069*					
(17)	Clear about Technology	.51001*	.43989*	.59126*	-.14231*	-.09808	-.15533*	-.31459*	-.39194*	-.40600*	.64579*	.26773*	-.29437*	-.36771*	.00266	.23792*	.56820*				
(18)	Provide Better Function	.10787	-.0785	.12728	.23746*	.51058*	.60228*	.11028	.33202*	.37869*	.16768*	-.06222	.47599*	.46795*	-.38327*	-.03884	-.09552	.04304			
(19)	Provide Better Quality	.24761*	.02831	.24781*	.23176*	.38735*	.59187*	.05558	.29034*	.34531*	.29764*	-.05212	.37901*	.37962*	-.29022*	.02802	.00509	.20518*	.85610*		
(20)	Highly Priced	-.09421	-.01965	-.07231	.27303*	.36434*	.50869*	.15644*	.25260*	.44525*	.01939	-.16281*	.36832*	.38532*	-.35417*	-.22136*	-.26423*	-.0806	.71833*	.67314*	

Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.75389; Bartlett Test of Sphericity = 1516.3755, $P < 0.001$

* $P < 0.05$

Table 5.6 QUARTIMAX Rotated Component Analysis Factor Matrix

Variables	Naming of Factors	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Communality	Cronbach Alpha*
Provide Better Function	Superior Product Profile	.91363					.67909	6757
Provide Better Quality		.89817					.55438	
Highly Pnced		.79433					.64229	
Novelty in Technology		.76158				.30301	.85011	
Budget Support		.64102	- 49691				.77389	
CEO Support		.63640	-.51638			43785	.71874	
Complexity in Technology		.44041	-.42082				81455	
Clear about Technology	Company Synergy and Competence		.81074				.74386	7962
Familiar with Technology			.78180				60013	
Familiar with Production Process			.68613	- 39330			.73394	
Familiar with Marketing			67830				72705	
Available Core Technology			.61941	- 40663	.38812		75024	
Complexity in Production Process	Manufacturing Difficulty			85388			.71383	7407
Available Key Parts				- 75030	.30594		68027	
Novelty in Production Process		35881		.63829	49765		65905	
Clear about Market Place	Project Clarity				.75789		63488	.6271
Complexity in Project Management		46553		.32486	-.56365		75397	
Clear about Product Specification			50836		.53459		85438	
Novelty in Market Place	Product Uniqueness	.53853				.65838	89446	.5807
Market Initiated Idea		- 36061			33418	- 63997	70774	
							Total	
Eigenvalue		6 37847	3 56352	1 85484	1.62780	1 06242	14 48705	
Percentage of Variance Explained		31 9	17 8	9 3	8 1	5 3	72 4	

* Q = 129 7344, P < 0 001

Superior Product Profile

This dimension consists of seven variables which describe how superior a product is, in terms of product function, quality, novelty, and complexity of technology employed, how the product is priced, the financial commitment, and the support from CEO. A "high profile NPD" depicts superior function and quality, commanding a higher price while employing more novel and complex technology in product design, and better financial and CEO support during new product development.

Company Synergy and Competence

This dimension consists of five variables which tap the level of capability of the firm and its familiarity with the project. Variables are: (1) Knowledge of the technology required for a product and (2) its availability, (3) the familiarity of the firm with the product in terms of technology employed, (4) the production process used, and (5) marketing related issues. High company synergy and competence denote that the firm has a great deal of knowledge about these issues.

Manufacturing Difficulty

This dimension consists of three variables that relate to manufacturing situations: (1) the newness and (2) complexity of the production process employed and (3) the availability of key parts. A new product invloving greater difficulty in manufacture has higher scores in both the newness and complexity of production process employed and a lower score in the availability of key parts.

Project Clarity

This dimension consists of three variables: the clearness of the firm about (1) the incumbent market place, (2) the project, and (3) product specifications from the very beginning of the project. A NPD situation displaying high project clarity means it has higher scores in both the clarity of market place and product specifications and has a lower score in the complexity of project management.

Product Uniqueness

The final dimension consists of two variables that describe the uniqueness of the product idea. (1) A unique product denotes a product whereby the original concept was initiated by in-house R&D and (2) the final product is considered very novel in the market place.

§5.5 NPD with Different External and Internal Contingent Situations

Hierarchical Cluster Analysis is used to classify sample cases into groups that encountered different external and internal contingent situations. Statistical algorithms for clustering the cases are based on the Average Linkage method[8] with Pearson Correlation[9] similarity measure to minimize variance within the groups and maximize variances between groups. Although other methods of clustering (e.g., Ward's method with Euclidean Distance) were also conducted, these solutions shared a similar pattern as the present statistical outcomes. In addition, researchers have suggested that such a combination of method and measure (i.e., Between-groups Linkage with Pearson Correlation) is appropriate in terms of classification accuracy while using Cluster Analysis (e.g., Cunningham and Ogilvie, 1972; Mezzich, 1978; Edelbrook and McLaughlin, 1980; Punj and Stewart, 1983).

NPD with Different External Contingent Situations

Table 5.7 shows the summary of Cluster Descriptors of NPD under different external contingent situations. Three contingent factors representing the market situations/conditions emerge from the five external contingent variables, i.e., (1) the turbulent situation, (2) the declining situation, and (3) the stable situation. NPD in a ***turbulent market*** faces a short product life cycle in a highly competitive market with a high market potential. NPD in a ***declining market*** covers products with a longer product life cycle and moderate competitive market with a low market potential. NPD in a ***stable market*** encounters a longer product life cycle and low market competition but in a market with high potential. Results of Discriminant Analysis (Table 5.8, Table 5.9) strongly suggest a robust classification of these clusters (with all Wilks' Lambdas below 0.80 and all ANOVA F statistics significant at $P < 0.001$ level). The classification matrix for the three-group Discriminant Analysis also shows a healthy 94.64% of correct group classification.

NPD with Different Internal Contingent Situations

Factor scores derived from the Factor Analysis of 20 situational variables are used for clustering the sample cases in an attempt to reflect NPD internal situations/conditions. Four types of NPD are eventually identified from the five internal contingent factors, namely, (1) the Easy-to-Produce Radicals, (2) the Hard-to-Produce Radicals, (3) the Untried Incrementals, and (4) the Tried and Tested Incrementals (Table 5.10).

Easy-to-Produce Radicals indicate high profile new products which are highly novel in the marketplace. They involve a high uncertainty at the beginning of product development, high

Table 5.7 Summary Cluster Descriptors of NPD under External Contingent Situations

Descriptions	NPDs under the Dynamics of Marketplace		
	Cluster 1 Turbulent Market	Cluster 2 Declining Market	Cluster 3 Stable Market
	NPDs with short product life cycle, high market competition, and high market potential	NPDs with long product life cycle, moderate market competition, and low market potential	NPDs with long product life cycle, low market competition, and high market potential
Expected Product Life Cycle (in months)	34.51111	75.29730	81.26667
Predicted Market Growth	7.62222	5.72973	7.96667
Estimated Market Demand	7.35556	5.64865	7.40000
Intensity of Price Competition	6.02222	4.59459	3.76667
Existence of a Big Competitor	6.51111	4.89189	3.13333
Number of Cases (Total = 112)	45	37	30

a) Method for Cluster analysis is based on the comparison of between-groups linkage with Pearson Correlation results.
b) Predicted market growth, market demand, price competition, and existence of a big competitor are based on a 9-point Likert-type scale where 1 = completely disagree with the statement and 9 = completely agree with the statement.

Table 5.8 Summary of Sequential Discriminant Analysis for External NPD Contingent Situations

Idependent Variables	Standardized Canonical Discriminant Function Coefficients		Wilks' Lambda	F
	Function 1	Function 2		
Expected Product Life Cycle (in months)	-.77072	-.33547	.75019	18.1479***
Predicted Market Growth	.68155	-.28064	.57461	40.3465***
Estimated Market Demand	.46961	-.19692	.62700	32.4225***
Intensity of Price Competition	-.22958	.37313	.76550	16.6954***
Existence of a Big Competitor	.08086	.70575	.64125	30.4897***

** P < .01, *** P< .001

Table 5.9 Classification Matrix for Three-Group Discriminant Analysis for External NPD Contingent Situations

Actual Group	Number of Cases	Predicted Group Membership		
		Turbulent Market	Declining Market	Stable Market
Turbulent Market	45	44 97.8%	0 .0%	1 2.2%
Declining Market	37	1 2.7%	34 91.9%	2 5.4%
Stable Market	30	2 6.7%	0 .0%	28 93.3%

Percent of "grouped" cases correctly classified is 94.64%.

familiarity of the firm with the product, and they are simple to manufacture. ***Hard-to-Produce Radicals*** also indicate high profile new products which are highly novel in the marketplace. They also contain a high uncertainty at the beginning of product development, but the manufacturing procedure is difficult and complex. ***Untried Incrementals*** represent low profile new products which are new in the marketplace. They experience a low level of uncertainty at the beginning of product development. The developers have little experience in developing such classes of product and somehow experience difficulty in the manufacturing stage. ***Tried and Tested Incrementals*** also represent low profile new products with low novelty in the marketplace. They have low uncertainty at the beginning of product development. The developers are very familiar with developing such classes of product and feel no difficulties in the manufacturing stage.

Discriminant Analysis shows all Wilk's Lambdas of each factor are below 0.9 and all F values of ANOVA results are significant at least at $P < 0.01$ level, which indicates good distinction among all discriminant functions. The classification matrix for four-group Discriminant Analysis also presents a 91.96% of correct group classification (Table 5.11, Table 5.12). The results

Table 5.10 Summary of Cluster Descriptors for the NPD under Internal Contingent Situations

		Cluster Descriptors			
		Cluster 1 Easy-to-Produce Radicals	Cluster 2 Hard-to-Produce Radicals	Cluster 3 Untried Incrementals	Cluster 4 Tried and Tested Incrementals
Descriptions		very high profile new products with high novelty in the marketplace; uncertainty was high at the beginning of product development; very easy manufacturing; the firm was familiar with this product class.	very high profile new products with high novelty in the marketplace; uncertainty was high at the beginning of product development; difficult or complex in manufacturing.	low product profile but new in marketplace; uncertainty was low at the beginning of product development; a minor difficulty in manufacturing; the firm was unfamiliar with such a product class.	low product profile and low novelty in marketplace; uncertainty was low at the beginning of product development; no difficulty in manufacturing; the firm was familiar with such a product class.
Factor 1:	Superior Product Profile	.47301	.29792	-.41534	-.21488
Factor 2:	Company Synergy	.21987	-.03396	-.60388	.49517
Factor 3:	Manufacturing Difficulty	-1.05848	1.01885	-.15199	.24808
Factor 4:	Project Clarity	-.53658	-.73915	.70620	.33610
Factor 5:	Product Uniqueness	.37568	.35656	.39688	-1.13635
Number of Cases (Total = 112)		27	24	33	28

Method for Cluster analysis is based on the comparison of between-groups linkage with Pearson Correlation results. The cluster descriptors are based on factor scores that have a mean of zero and standard deviation of one. For instance, -.03396 (see second column, second row) indicates an about average quality on a particular factor.

indicate a robust classification of NPD based on different internal contingent factors.

Table 5.13 shows the distribution of the sample based on the internal and external contingent factors. Chi-square test suggests that these two dimensions of contingent factors are not independent of each other. In other words, to some extent, the impact of internal factors upon firm NPD behaviour is moderated by external ones. Given this, the interaction between both dimensions of factors should be considered simultaneously so as to provide deeper insight into firm NPD behaviour. However, due to small group sample size, it is statistically inappropriate for the current study to conduct parametric analysis based on such a 12-cell classification. The following analyses will therefore look at these two dimensions of factors separately, without considering their possible interactions.

§5.6 Profiles of Firms with Different External and Internal

Table 5.11 Summary of Sequential Discriminant Analysis for Internal NPD Contingent Situations

Idependent Variables		Standardized Canonical Discriminant Function Coefficients			Wilks' Lambda	F
		Function 1	Function 2	Function 3		
Factor 1:	Superior Product Profile	.47350	.46992	-.22417	.86446	5.6447**
Factor 2:	Company Synergy	-.19418	.44180	-.61297	.81670	8.0798***
Factor 3:	Manufacturing Difficulty	-.51604	.60776	.62087	.49361	36.9325***
Factor 4:	Project Clarity	-.58141	-.78267	.14856	.63377	20.8031***
Factor 5:	Product Uniqueness	.87490	-.12995	.50369	.56544	27.6670***

** P < .01, *** P< .001

Table 5.12 Classification Matrix for Four-Group Discriminant Analysis for Internal NPD Contingent Situations

Actual Group	Number of Cases	Predicted Group Membership			
		Easy-to-Produce Radicals	Hard-to-Produce Radicals	Untried Incrementals	Tried and Tested Incrementals
Easy-to-Produce Radicals	27	26 96.3%	1 3.7%	0 .0%	0 .0%
Hard-to-Produce Radicals	24	0 .0%	23 95.8%	0 .0%	1 4.2%
Untried Incrementals	33	1 3.0%	3 9.1%	29 87.9%	0 .0%
Tried and Tested Incrementals	28	0 .0%	2 7.1%	1 3.6%	25 89.3%

Percent of "grouped" cases correctly classified is 91.96%.

Table 5.13 Sample Distribution in the Space of Internal and External Contingent Factors

Environmental Situations	Task Differnece				Total
	Easy-to-Produce Radicals	Hard-to-Produce Radicals	Untried Incrementals	Tried & Tested Incrementals	
Turbulent Market	4 (3.6%)	11 (9.8%)	13 (11.6%)	17 (15.2%)	45 (40.2%)
Declining Market	12 (10.7%)	6 (5.4%)	11 (9.8%)	8 (7.1%)	37 (33.0%)
Stable Market	11 (9.8%)	7 (6.3%)	9 (8.0%)	3 (2.7%)	30 (26.8%)
Total	27 (24.1%)	24 (21.4%)	33 (29.5%)	28 (25%)	112 (100.0%)

Pearson Chi-square=13.87749; Degree of Freedom=6; P<0.05.

Contingent Situations

So far, this study has differentiated NPD according to external and internal contingent factors. This section provides background information on sample firms under these contingent situations. Two sets of variables are used to portray the sample firms. The first set of ten variables presents profiles of these firms, which include: years since the company was established, annual sales, number of employees, R&D employees as a percentage of the workforce, turn-over rate of R&D employees, number of new product launches in the last five years, percentage of NPD that have never been commercialized, percentage of NPD commercial success, new product sales as a percentage of total sales, and R&D expenditure as a percentage of annual sales. The second set of variables characterizes the nature of corporate-level management approaches of these firms based on subjective comparisons with their competitors. This includes: extent of R&D investment, conservative or risk-taking management style, sensitivity and responsiveness to the marketplace/technology, manufacturing style, and general pricing policy.

Firms with Different External Contingent Situations

ANOVA and Duncan Test[10] are employed to compare the company profiles and corporate management approaches of the sample firms under different contingent situations (Tables 5.14 and 5.15). According to the statistical results, overall, only four out of fifteen descriptive variables show significant differences under external contingent factors. This suggests that corporate-level activities are in effect less sensitive to external contingent factors. Firms tend

Table 5.14 Company Profile by External NPD Contingent Factors

Company Profile	Environmental Situations (a) (1) Turbulent Market (n=45)	(2) Declining Market (n=37)	(3) Stable Market (n=30)	F	Duncan Results*
Years Since the Company was Established	13.2000 (7.7242)	22.2973 (15.7266)	16.8333 (11.0144)	6.1042** (c)	(2) > (1) (b)
NPD Sales as a Percentage of Total Sales (%)	.8589 (.2317)	.6959 (.2842)	.7333 (.3125)	4.0274*	(1) > (2)
R&D Expenditure as a Percentage of Annual Sales (%)	.0649 (.0451)	.1091 (.1812)	.1354 (.1678)	NS	(3) > (1)

(a) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(b) (2) > (1) denotes that the mean of group (2) is significantly larger than the mean of group (1), based on P<.05 level.
(c) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 5.15 Corporate-level Strategic Profiles by External NPD Contingent Factors

Corporate-level Strategic Profiles	Environmental Situations (b) (1) Turbulent Market (n=45)	(2) Declining Market (n=37)	(3) Stable Market (n=30)	F	Duncan Results*
Response Speed to Market and Technology	7.2222 (a) (1.7951)	6.0541 (1.9717)	7.7000 (1.6640)	7.5100*** (d)	(2) < (1), (3) (c)

(a) Group mean and standard deviation (in parentheses) are based on 9-point Likert-type scales where 1 denotes very slow and inactive to the changes of market and technology; 9 denotes very quick and active to the changes.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (2) < (1), (3) denotes that the mean of group (2) is significantly smaller than the means of group (1) and group (3), based on P<.05 level.
(d) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

to appreciate and highlight their past successful experiences and therefore insist on a rigid pattern of managerial style, although external situations may have already changed (Leonard-Barton, 1992a). However, in some ways, the fundamental characteristics of these firms do vary according to their incumbent environment. Bearing in mind the definitions of turbulent, declining, and stable market situations (Section 5.5), first of all, the firms encountering a declining market situation tend to be those that have been longer established (mean = 22.3 years old) than those in a turbulent market situation (mean = 13.2 years old). Secondly, firms in a turbulent market situation tend to have a higher percentage of new product sales (mean = 85.89%) than those in a declining market (mean = 69.59%). Thirdly, firms in a turbulent market situation tend to have less R&D investment (mean = 5.49%) than those in a stable market situation (13.54%). This may be due to the consideration of risk while investing in R&D during very high market

Table 5.16 Company Profile by Internal NPD Contingent Factors

Company Profile	Task Differences (a)				F	Duncan Results*
	(1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)		
Years Since the Company was Established	11.0370 (9.8819)	20.7083 (15.5325)	18.1212 (10.9623)	18.9643 (11.1637)	3.3792* (c)	(1) < (2), (3), (4)
Total Number of Employees	562.22 (1379.20)	1502.71 (1752.16)	1175.61 (1737.16)	736.64 (782.90)	NS	(2) > (1) (b)
R&D Member as a Percentage of Total Employees (%)	.3489 (.2690)	.2080 (.2072)	.1258 (.1489)	.1226 (.0913)	8.9708***	(1) > (2), (3), (4)
NPD Market Success (%)	.8489 (.2028)	.7192 (.2166)	.6652 (.3420)	.7404 (.2153)	NS	(1) > (3)
NPD Sales as a Percentage of Total Sales (%)	.9130 (.1707)	.8271 (.2152)	.6652 (.3244)	.7125 (.2996)	5.1312**	(1) > (3), (4) (2) > (3)
R&D Expenditure as a Percentage of Annual Sales (%)	.2136 (.2419)	.0689 (.0434)	.0612 (.0544)	.0564 (.0434)	9.9820***	(1) > (2), (3), (4)

(a) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(b) (2) > (1) denotes that the mean of group (2) is significantly larger than the mean of group (1), based on P<.05 level.
(c) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 5.17 Corporate-level Strategic Profiles by Internal NPD Contingent Factors

Corporate-level Strategic Profiles	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)		
Level of R&D Investment	8.3333 (a) (.8321)	7.8333 (1.5511)	7.4545 (1.4381)	7.3214 (1.3892)	3.2379* (d)	(1) > (3), (4) (c)
Risk Taking in Management Decision	5.7407 (2.1772)	6.3333 (1.7362)	4.9394 (1.7131)	5.9643 (1.6884)	3.0409*	(3) < (2), (4)
Manufacturing Style (for small scale variant model production)	4.4444 (2.7503)	5.6667 (1.8337)	4.3030 (1.8789)	5.1071 (2.1316)	NS	(2) > (3)
High-priced High-profiled Product Policy	7.2963 (1.6365)	6.0833 (1.7173)	5.2727 (1.9084)	6.1429 (1.8199)	6.3924***	(1) > (2), (3), (4)

(a) Group mean and standard deviation (in parentheses) are based on 9-point Likert-type scales where 1 denotes very slow and inactive to the changes of market and technology; 9 denotes very quick and active to the changes.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (1) > (3), (4) denotes that the mean of group (1) is significantly larger than the means of group (3) and group (4), based on P<.05 level.
(d) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

turbulence. Finally, firms in a declining market situation tend to be less alert in terms of the situations/conditions of technology and marketplace while firms in a turbulent or a stable market seem to have higher responsiveness to their external environment.

Firms with Different Internal Contingent Situations

Tables 5.16 and 5.17 present the nature of firms which encountered different internal contingent factors. ANOVA and Duncan results show that the characteristics and the corporate strategic choices of firms tend to be different while they are proficient in different NPD. Firms proficient in developing Easy-to-Produce Radicals seem to be the youngest (mean = 11 years old) of all firms. Their firm size also tends to be smaller (mean number of employees = 562) compared with those firms developing Hard-to-Produce Radicals (mean = 1,502). However, of all firms the Easy-to-Produce Radicals have the highest percentages of R&D members among their employees (mean = 34.89%). They also have higher NPD success rates (mean = 84.89%) than those developing Untried Incrementals (mean = 65.52%). In turn, they have the highest level of R&D expenditure among all firms (mean = 21.36%). Statistical results also suggest that firms developing radical innovations (both Easy-to-Produce and Hard-to-Produce) depend more upon new product sales than those of incremental innovations.

The sample firms also show differences in corporate management approach to different internal contingent situations. Firms developing Easy-to-Produce Radicals tend to invest more resources in R&D while compared with those who produce incremental NPD. They also seem to accept a high-profiled, high-priced concept in developing their general product policy. On the other hand, the incremental producers tend to put less effort into R&D and tend to rely more on price competition. Firms developing Untried Incrementals also tend to have a risk-averse attitude while making managerial decisions. They also rely heavily on mass production so as to take advantage of cost leadership. According to the in-depth interviews, these firms tend to be followers who develop only the products that have already been proved successful in the marketplace, although they may in the event have little experience of the new business.

§5.7 Summary of This Chapter

This chapter provides a preliminary investigation of research data. Using interviewees' perceptions and accounts of specific NPD projects, the underlying structure of NPD situations/conditions is revealed. Factor analysis, as well as cluster analysis, enabled sample cases to be categorised according to external and internal NPD contingent situations. For external NPD environmental dynamics, three different situations are identified, i.e., the turbulent situation, the declining situation, and the stable situation. For internal NPD situations/conditions, four different task types appear to emerge, namely, Easy-to-Produce Radicals, Hard-to-Produce Radicals, Untried Incrementals, and Tried and Tested Incrementals. Discriminant Analysis and supporting literature concerning the use of statistical methods for analyses suggest that the classifications of sample cases are appropriate and robust.

ANOVA and the Duncan Test are employed to provide background information of sample firms confronting the variety of contingent internal and external situations. Statistical results show that firms tend to adhere to traditional/established patterns of management and corporate strategic choices, ignoring the situations/conditions of external contingent factors. However, firms that are proficient in different types of NPD do reflect different characteristics in terms of company profiles and attitudes in corporate decision making. This suggests that the adaptation of corporate managerial structures is more likely to be triggered by in-house strategic choices, rather than external environmental conditions.

The following chapters examine project-level NPD managerial efforts under both external and internal contingent situations. Chapter Six firstly presents the empirical results of NPD information acquisition under contingent situations.

Notes

The following notes concerning statistical methodologies used in this chapter are mainly based on the efforts of: (1) Stewart, D.W. (1981), 'The Application and Misapplication of Factor Analysis in Marketing Research,' *Journal of Marketing Research*, 18, February, 51-62. (2) Punj, G., D.W. Stewart (1983), 'Cluster Analysis in Marketing Research: Review and Suggestions for Application,' *Journal of Marketing Research*, 20, May, 134-48. (3) Churchill, Jr., G.A. (1983), *Marketing Research: Methodological Foundations*, Chicago: The Dryden Press. (4) Dillon, W.R. and M. Goldstein (1984), *Multivariate Analysis: Methods and Application*, Taipei: Wha Tai Press. (5) SPSS, Inc., *SPSS User's Guide*, Chicago, 1990. (6) SPSS, Inc., *SPSS Advanced Statistics Guide*, Chicago, 1990. (7) Hair, Jr. J.F., R. Anderson, R.L. Tatham, and W.C. Black (1992), *Multivariate Data Analysis with Readings*, New York: Macmillan Publishing Company. For more detailed descriptions of these statistical methods please refer to Chapter Four.

1. Principal-Components Analysis is used to form uncorrelated linear combinations of the observed variables based on the total variance. The first component has maximum variance and the successive components explain progressively smaller portions of the variance and are all uncorrelated.

2. Kaiser-Meyer-Olkin Measure is an index for comparing the magnitudes of the observed correlation coefficients to the partial correlation coefficients. If the sum of the squared partial correlation coefficients between all pairs of variables is small when compared to the sum of the squared correlation coefficients, it is close to 1. Small values indicate that a factor analysis may not be appropriate, since correlations between pairs of variables cannot be explained by the other variables. Kaiser describes values in the 0.90's as marvellous, in the 0.80's as meritorious, in the 0.70's as middling, in the 0.60's as mediocre, in the 0.50's as miserable, and below 0.50 as unacceptable.

3. Bartlett Test is a statistic that can be used to test the hypothesis that the correlation matrix is an identity matrix (a matrix in which all diagonal terms are 1 and off-diagonal terms 0). It requires that the data be a sample from a multivariate normal population. If the null hypothesis that the population correlation matrix is an identity matrix cannot be rejected, and the sample size is reasonably large, the use of multivariate analysis is appropriate.

4. QUARTIMAX is a rotation method of Factor Analysis that minimizes the number of factors needed to explain each variable. It simplifies the interpretation of the observed variables.

5. Scree Test is a plot of the variance associated with each factor. It is used to determine how many factors should be kept. Typically the plot shows a distinct break between the steep slope of the large factors and the gradual trailing of the rest (the scree).

5. Communality is the amount of variance which an original variable shares with all other variables included in the analysis. Large communalities indicate that a large amount of the variance in a variable has been extracted by the factor solution.

7. Cronbach Alpha is a commonly used measure of reliability for a set of two or more construct indicators. Values range between 0 and 1.0 with higher values indicating higher reliability among the indicators.

8. Average-linkage is a method for clustering cases into clusters. This method combines clusters to minimize the average distance between all pairs of items in which one member of the pair is from each of the clusters. This method uses information about all pairs of distances, not just the nearest or the furthest and tends to combine clusters with small variances.

9. Pearson Correlation is a measure of linear association ranging from -1 to +1, with a value of 0 indicating no linear association.

10. Duncan Test is a multiple comparison procedure that ranks the group means from smallest to largest and uses the distance or number of steps that two means are apart in this ranking in computing the range value for each comparison. The test is based on the assumption that the larger the number of means being compared, the more likely will significantly different comparisons occur. In this procedure, the probability of finding a significant difference, given that the two groups are in fact equal, is sometimes less than, and never greater than, the specified significance level.

Chapter Six

The Management of NPD Information Acquisition

6

In the last chapter NPD cases are classified into clusters based on their underlying external and internal project situations/conditions. Within such classifications, characteristics and strategic profiles of sample firms are compared. Statistical results show that firms tend to be different in nature, while they are proficient in different product innovations. This chapter further researches into NPD contingency management at project level. Based on the assertion that the core of NPD is essentially the management of information processing and knowledge accumulation, this chapter describes how information acquisition behaviour adapts to different contingent situations. Results from ANOVA and Duncan Test suggest that information acquisition activities of firms at project level do vary significantly according to different market situations as well as different task types.

6 The Management of NPD Information Acquisition

§6.1 Introduction

Firms perceive a certain type of information as having high impact upon their success and therefore they acquire such information. To understand the information acquisition activities of firms during NPD, one should first examine how firms rate the necessity of different types of information and in addition observe their actual acquisition behaviour. This chapter investigates in detail the whole process of NPD information acquisition. This process, according to the conceptual framework presented in Chapter Three, consists of the identification of critical NPD information, information sources, timing for acquisition, efforts spent on acquisition activities, and the key players in the acquisition process. Ten information types are specified for this study, i.e., (1) goal/strategy related information, (2) market related information, (3) regulation/law/ industrial standard related information, (4) supplier/component related information, (5) competitor related information, (6) customer related information, (7) cost/price related information, (8) product related information, (9) technology/science related information, and (10) manufacturing related information. ANOVA and Duncan Test are employed to compare the acquisition activities of NPD in different external and internal contingent situations. For each of the following sections, the research hypothesis is presented to highlight the main issue in the discussion. Key findings from statistical results are then provided, so as to confirm or reject the hypothesis. Finally, these research findings are further discussed, in an attempt to assess the current observations in the light of previous academic efforts.

§6.2 Contingent Situations and The Necessity of NPD Information

Hypothesis 1.1: Management's perceived importance of a specific type of information required for successful NPD projects varies significantly with the type of new product project undertaken.

Hypothesis 1.2: Management's perceived importance of a specific type of information required for successful NPD projects varies significantly with the dynamics of its incumbent marketplace.

Hypothesis 1.3: For successful NPD, the actual efforts spent in acquiring a specific type of information vary significantly with the type of new product project undertaken.

Hypothesis 1.4: For successful NPD, the actual efforts spent in acquiring a specific type of information vary significantly with the dynamics of its incumbent marketplace.

To identify the necessity of different types of information for NPD, two measurement approaches are used. The first approach is based on the interviewees' self-reported perception of the need for any particular kind of information. Such a perception is measured using a 9-point Likert-type scale, in which the necessity for information is rated based on a scale from extremely unnecessary to extremely necessary. The second approach observes the actual efforts of firms spent in acquiring information during NPD. Two variables are employed for measuring such efforts to acquire information. The first variable examines whether the firm has actually acquired certain information during NPD, especially for a particular project. A certain type of information is regarded as having a high impact upon a particular NPD when it has been actually acquired during the development process. The second variable examines the amount of time invested in information acquisition during NPD for those who have actually acquired the specified information. The period spent in information acquisition is measured by how many phases[1] of NPD have been actually used in such an action. The more the phases of NPD spent in information acquisition, the more important the information is.

6.2.1 *Information Requirements under External Contingent Situations*

Key Findings

Tables 6.1, 6.2, and 6.3 compare NPD information requirements under different external contingent situations. Based on the measurement of self-reported perception about the importance of NPD information, ANOVA and Duncan results suggest that NPD in a turbulent

Table 6.1 External Contingent Situations and the Necessity of Information

Information Type	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
Market Related Information	6.6905 (a) (2.5422)	5.9286 (2.7070)	4.8276 (2.7001)	4.2845* (d)	(1) > (3) (c)
Supplier, Component Related Information	6.0714 (2.4534)	4.7500 (3.1461)	3.7241 (3.3689)	5.6066**	(1) > (3)
Cost/Price Related Information	5.4762 (2.1779)	5.1429 (2.5344)	4.0000 (2.4495)	3.4791*	(1) > (3)

(a) Group mean and standard deviation (in parentheses) are based on a 9-point Likert-type scale where: 1 = Extremely Unnecessary, 5 = Neutral, 9 = Extremely Necessary.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (1) > (3) denotes that the mean of group (1) is significantly larger than the mean of group (3), based on $P<.05$ level.
(d) * $P<.05$, ** $P<.01$, NS: Not Significant. All Duncan results are based on $P<.05$ comparison.

Table 6.2 External Contingent Situations and the Acquisition or Non Acquisition of Information During NPD

Information Type	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
Competitor Related Information	1.2143 (a) (.7507)	1.6429 (.4880)	1.2759 (.7510)	3.5299* (d)	(2) > (1), (3) (c)
Manufacturing Related Information	1.8333 (.3772)	1.5357 (.8381)	1.4138 (.9070)	3.3513*	(1) > (3)

(a) Mean and standard deviation (in parentheses) are based on the following calculation:
0 = did not acquire, define, or generate this information during NPD.
1 = this information was regularly scanned for all projects or is acquired from other projects.
2 = this information has been exclusively acquired for the particular NPD.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (2) > (1), (3) denotes that the mean of group (2) is significantly larger than the means of group (1) and group (2), based on $P<.05$ level.
(d) * $P < .05$, NS: Not Significant. All Duncan results are based on $P<.05$ comparison.

Table 6.3 External Contingent Situations and the Period Spent in Acquiring Information

Information Type	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
Competitor Related Information	.5714 (a) (.6678)	1.0357 (.9616)	.6552 (.8567)	NS (d)	(2) > (1) (c)
Technology / Science Related Information	1.3333 (.9283)	1.5714 (.8789)	2.0690 (1.1317)	4.8815**	(3) > (1)

(a) Group mean and standard deviation (in parentheses) are based on the number of NPD phases that were used to acquire information. Possible number of phases ranging from 0 to 7.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (2) > (1) denotes that the mean of group (2) is significantly larger than the mean of group (1), based on $P<.05$ level.
(d) * $P<.05$, ** $P<.01$, NS: Not Significant. All Duncan results are based on $P<.05$ comparison.

market tends to produce a higher anxiety for information acquisition then those in a stable market. However, such an anxiety for information is only centred on the acquisition of market, supplier/component, and cost/price related information. For other information types, there is no evidence to show that the need for information is contingent upon external NPD situations. Research hypothesis 1.2 is partially supported.

While examining the actual acquisition activities, NPD in a declining market seems more likely to invest resources in acquiring competitor related information than NPD in other situations. NPD under turbulent market conditions tends to put into action the acquisition of manufacturing related information, while NPD under stable market conditions seems to spend more time in acquiring technology/science related information. For other information types, there is no evidence to suggest that actual information acquisition is contingent upon external NPD situations. Research hypothesis 1.4 is also partially supported.

Discussions

Firms encountering a turbulent market may feel a higher uncertainty about the external world. A greater amount of information may be necessary so as to reduce the risks. Similar assertions have been hypothesized by Daft and his colleagues, that firms in a highly uncertain situation need to acquire a greater amount of information (Daft and Macintosh, 1981; Daft and Weick, 1984; Daft and Lengel, 1986).

However, in considering the efforts spent in acquiring NPD information, statistical results reveal the inconsistencies of firms between their self-reported perceptions and their actual actions. As firms are often limited by availability of resources (e.g., time, budget, manpower), they may encounter difficulties in doing all the things that are perceived as highly important. In a turbulent situation, because the marketplace is so dynamic, competitor and technology/science related information may rapidly lose significance. Therefore, it is no longer worth pursuing immediately. Instead, to maintain the capability of fast manufacturing seems to be much more important. On the other hand, firms in a declining market may worry about losing customers. Competitor related information is not only a matter of necessity but in effect a means for maintaining survival. Finally, firms in a stable market seem to spend more actual time in acquiring technology/science related information. By definition, the stable market situation is a state which has a longer product life cycle, a higher market growth rate, and a lower level of market competition. In other words, this is a situation that provides opportunity for oligopolization or even monopolisation. According to the Schumpeterian, such a situation encourages innovations (e.g., Schumpeter, 1942), which consume a great deal of technology/science related information.

6.2.2 *Information Requirements under Internal Contingent Situations*

Key Findings

Chapter Five categorises NPD cases into different task types, based on internal project situations. These task types include: Easy-to-Produce Radicals, Hard-to-Produce Radicals, Untried Incrementals, and Tried and Tested Incrementals. Tables 6.4, 6.5, and 6.6 examine NPD information requirements associated with these task types. The current study finds significant differences among the task types in terms of the perceived importance of information required by NPD. Research hypothesis 1.1 is supported. Overall, those involved with NPD that are radical or unfamiliar to the firm tend to perceive product and technology/science related information as critical to their success and, in the meantime, devalue the impact of customer, cost/price , and manufacturing related information.

While considering the actual efforts spent in acquiring NPD information, statistical analyses reveal similar results in comparison with those of self-reported perceptions about the impact of information. The decision to acquire or not to acquire a certain type of information, and the period spent in actually acquiring information, vary significantly according to the type of new product project undertaken. Hypothesis 1.3 is also supported.

Discussions

Easy-to-Produce Radicals tend to give more attention than others to acquiring goal/strategy, product, and technology/science related information. In the mean time, they also tend to devalue the impact of market, supplier/component, customer, cost/price, and manufacturing

Table 6.4 Internal Contingent Situations and the Necessity of Information

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Goal/Strategy Related Information	7.6522 (a) (1.4660)	6.3000 (1.9494)	5.9643 (2.9629)	4.8214 (3.0678)	5.3157** (d)	(1) > (3), (4) (c)
Market Related Information	4.4783 (2.8899)	7.9000 (1.9448)	5.8571 (2.7041)	5.7857 (2.3311)	6.6963***	(2) > (1), (3), (4)
Regulation, Law, and Industrial Standard	4.3913 (3.2993)	5.4500 (2.9465)	3.5714 (3.1906)	1.9286 (2.1244)	6.3446***	(2) > (3), (4) (1) > (4) (3) > (4)
Supplier, Component Related Information	2.6957 (2.7041)	7.6000 (1.5694)	4.4286 (3.1083)	5.6429 (2.5993)	13.5254***	(2) > (1), (3), (4) (4) > (1) (3) > (1)
Customer Related Information	3.0000 (3.3029)	2.5500 (3.1867)	2.3214 (2.9320)	7.0714 (3.0420)	14.0654***	(4) > (1), (2), (3)
Cost/Price Related Information	4.0435 (2.3448)	4.6000 (.9403)	4.1786 (2.7087)	6.7143 (2.0522)	8.8165***	(4) > (1), (2), (3)
Product Related Information	8.4783 (.7305)	8.5500 (.8870)	8.0714 (1.4889)	5.6071 (2.6158)	17.8708***	(4) < (1), (2), (3)
Technology / Science Related Information	8.0000 (1.3817)	8.4500 (.6863)	8.0000 (1.8257)	4.6071 (3.4355)	17.3387***	(4) < (1), (2), (3)
Manufacturing Related Information	2.0000 (1.9540)	1.5000 (1.5390)	2.7500 (2.7972)	5.2500 (3.4601)	10.0899***	(4) > (1), (2), (3)

(a) Group mean and standard deviation (in parentheses) are based on a 9-point Likert-type scale where: 1 = Extremely Unnecessary, 5 = Neutral, 9 = Extremely Necessary.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (1) > (3), (4) denotes that the mean of group (1) is significantly larger than the means of group (3) and group (4), based on P<.05 level.
(d) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 6.5 Internal Contingent Situations and the Acquisition or Non-Acquisition of Information During NPD

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Goal/Strategy Related Information	1.8696 (a) (.3444)	2.0000 (.0000)	1.6429 (.6785)	1.3929 (.8751)	4.6045** (d)	(4) < (1), (2) (c)
Regulation, Law, and Industrial Standard	1.0435 (.7057)	1.3500 (.4894)	1.1071 (.6289)	.9643 (.5762)	NS	(2) > (4)
Supplier, Component Related Information	.9565 (.9283)	1.5500 (.5104)	1.7143 (.4600)	1.5357 (.5079)	6.8902***	(1) < (2), (3), (4)
Customer Related Information	.5652 (.8435)	.3500 (.7452)	.3929 (.7860)	1.4286 (.7902)	10.7836***	(4) > (1), (2), (3)
Technology / Science Related Information	1.9565 (.2085)	2.0000 (.0000)	1.9643 (.1890)	1.5000 (.5092)	15.9502***	(4) < (1), (2), (3)
Manufacturing Related Information	1.0435 (1.0215)	1.8000 (.6156)	1.8929 (.4163)	1.7143 (.4600)	8.2954***	(1) < (2), (3), (4)

(a) Mean and standard deviation (in parentheses) are based on the following calculation:
0 = did not acquire, define, or generate this information during NPD.
1 = this information was regularly scanned for all projects or is acquired from other projects.
2 = this information has been exclusively acquired for the particular NPD.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (4) < (1), (2) denotes that the mean of group (4) is significantly smaller than the means of group (1) and group (2), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 6.6 Internal Contingent Situations and the Period Spent in Acquiring Information

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Market Related Information	.3913 (a) (.4990)	.7000 (.5712)	.8929 (.8317)	.8571 (.8034)	NS (d)	(1) < (3), (4) (c)
Supplier, Component Related Information	.4783 (.6653)	1.0000 (1.0761)	1.1071 (.9165)	.8929 (.8751)	NS	(3) > (1)
Competitor Related Information	.6087 (.7223)	.4500 (.5104)	1.1429 (1.0440)	.6071 (.7373)	3.7146*	(3) > (1), (2), (4)
Customer Related Information	.4348 (.8958)	.4000 (.8826)	.3571 (.8262)	1.2500 (1.0758)	5.6980**	(4) > (1), (2), (3)
Cost/Price Related Information	1.3043 (.4705)	1.7000 (.4702)	1.3929 (.6289)	1.6071 (.5669)	NS	(2) > (1)
Technology / Science Related Information	1.8261 (.8869)	1.5500 (.6863)	2.1429 (.8483)	.9643 (1.1380)	8.1543***	(4) < (1), (2), (3) (2) < (3)
Manufacturing Related Information	.8696 (1.0137)	.9500 (.3940)	1.3571 (.6215)	1.2857 (.9372)	NS	(3) > (1)

(a) Group mean and standard deviation (in parentheses) are based on the number of NPD phases that were used to acquire information. Possible number of phases ranging from 0 to 7.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (1) < (3), (4) denotes that the mean of group (1) is significantly smaller than the means of group (3) and group (4), based on P<.05 level.
(d) * P<.05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

related information. As they often encounter high uncertainty at the beginning of NPD and have little difficulty in the later manufacturing (see Chapter Five), it is obvious that they need to pay more attention to initial NPD strategic planing so as to clarify the general approach of the project. They also consume a great amount of product and technology/science related information because the radical nature of this product type. This supports the view of Brown and Karagozoglu (1989) and Keller (1994). They asserted that in the case of radical product innovation, firms need to enhance the processing of technology related information. On the contrary, the necessity of supplier/component, cost/price, and manufacturing related information is considered less important as the Easy-to-Produce Radicals are by definition easy to produce. Market and customer related information are also largely ignored, because this NPD type tends to focus on satisfying customers' future needs. A need in the future cannot be explained by current market and customer related information. Such an observation is highly consistent with the finding reported by Workman (1993), that marketing function should keep a low profile while dealing with high-tech product innovations.

Hard-to-Produce Radicals seem to be very keen to pursue all kinds of information, except customer related information. As this NPD type is often a project involving radical technology, it has a long development cycle, and requires heavy investment in prototyping and manufacturing; the uncertainty which emerges from both technology and the changing marketplace can be highly risky to the survival of the firm. As a result, firms developing this type of NPD need to process a great amount of information of most kinds, so as to reduce project uncertainty. This supports the findings of Hauptman (1986), Ito and Peterson (1986), and Keller (1994), that nonroutine tasks, or highly difficult projects, tend to have higher information needs. However, similar to Easy-to-Produce Radicals, a project aimed at evolving customers' future needs tends to devalue the "current" customer related information. A similar conclusion was also reported by Workman (1993).

Untried Incrementals are projects that are low in novelty but which involve uncertainty because the firm is unfamiliar with them. As a result, they consume more information than other incremental innovations. They tend to show higher anxiety than others for most information types, such as supplier/component, market, competitor, technology/science, and manufacturing related information. This confirms the assertion by Hauptman (1986) and Keller (1994) that nonroutine tasks or highly uncertain projects require a greater amount of information processing. However, firms seem to highly devalue customer related information while developing this type of new product. This may be due to the fact that Untried Incrementals are often imitations or modifications of existing successful products from other market segments (or from foreign markets), although they may be totally new to the local market and the firm. Therefore, there is little necessity for such products to re-examine formally market acceptability.

Tried and Tested Incrementals show quite a different pattern of information acquisition from other NPD types. For Tried and Tested Incrementals, customer, supplier/component, cost/price, and manufacturing related information seem to be highly important. They also tend to spend more time in acquiring market related information. However, other information types, such as goal/strategy, regulation, law, industrial standard, product, and technology/science related information, are less emphasised. As this NPD type is merely minor improvements of existing products, it is not a serious issue in terms of corporate strategic moves. Moreover, as firms are highly familiar with this type of NPD, they have already accumulated sufficient knowledge or information about product design, required technology, relevant regulations, law, and industrial standard from previous practices. On the other hand, as Tried and Tested Incrementals are developed to satisfy customers' current needs, understanding of consumer preference, speed in bringing product design through manufacturing, and capability to reduce both development and manufacturing costs to increase competitiveness, tend to be more critical. This leads firms to concentrate their information acquisition efforts on market and manufacturing related issues. Similar observation was reported by Brown and Karagozoglu (1989) that incremental innovations tend to focus on market development, rather than technological investigations. More recently, Atuahene-Gima (1995) also suggested a strong association between market orientation and the development of incremental innovations.

§6.3 Contingent Situations and the Characteristics of NPD Information Sources

> ***Hypothesis 2.1:*** *For successful NPD, the selection of information sources varies significantly with the type of new product project undertaken.*
>
> ***Hypothesis 2.2:*** *For successful NPD, the selection of information sources varies significantly with the dynamics of its incumbent marketplace.*

The sources of NPD information acquisition are examined in terms of their richness, bounded versus unbounded, primary versus secondary, and formal versus informal terms. As the current study is aimed at accessing a larger sample size of NPD projects, the limitations of time and budget do not allow the researcher to use a longitudinal approach such as Network Analysis for acquiring research data. On the other hand, as NPD is in effect a very complicated process that normally involves many people during quite a long period, there should be many possible external and internal contacts of project members during NPD. To remedy this problem, the current study uses a *post hoc* approach to identify information acquisition activities. The interviewees were requested to point out the most significant information sources for each information type during a particular NPD. These subjectively selected information sources are therefore categorized into different source types and act as the basis of the following analyses. The current study recognizes that the resulting picture of information acquisition does not fully represent actual situations. It is impossible however to identify thoroughly and recall in a *post hoc* manner such a large number of communications.

The following analyses concerning the bounded versus unbounded, primary versus secondary, and formal versus informal information sources are centred on the cases that have actually acquired certain types of information during NPD. As not all information types have been actually acquired during the development process for all NPD cases studied, the group sample size based on a certain information type may be small. This will weaken the validity of using ANOVA. However, according to the statistical formulation approach used by the Duncan test (Duncan, 1955, 1957), lack of a large sample size should not seriously limit the interpretation of analysis results. The sample size of each factor identified in the analysis is considered while calculating the Duncan's Multiple Range statistic, and therefore, the possibility that too small a sample size may affect the statistical significance level is eventually counteracted[2]. Furthermore, Harter (1957) provided detailed estimation of possible error rates in multiple comparisons when group sample size is small. According to his calculation, the small group sample size in some of the analysis has little effect in distorting the Duncan Test's results. Take an extreme example: in Table 6.10, one of the treatment for the Hard-to-Produce Radicals has a group sample size of only four cases. According to Harter (1957), in a single classification with four categories, a group sample size of four generates a possible type I error rate of about 1% and type II error rate of about 6% (at a significance level of $P = 0.05$). Therefore, in the cases with small group sample size, Duncan Test result is still meaningful for discussion.

The richness of information sources is measured by the number of different source types that were actually used during NPD to gain the particular information. According to such a definition, the larger the number of different sources identified, the richer the sources for this particular information. The bounded or unbounded information source is measured by the number of source types that were internal or external to the company. Bounded information is defined as the information acquired within the boundary of the organisation while the unbounded is that which is acquired from outside the company. The score for measuring the source that is bounded or unbounded is calculated by the percentage of bounded sources taking into account all sources that were used during NPD. When these sources are transferred to a scale of one to nine, one denotes that all information sources were from inside the company; nine denotes all information sources were from outside the company. The cases that did not acquire particular information during NPD (i.e., the number of sources is zero) were treated as system missing. The same calculation method was used to define in terms of percentages of information source usage, the primary versus the secondary sources and the formal versus informal sources respectively. Within the one to nine scale, the higher the scores of source characteristics, the more secondary or informal the sources that were used.

Key Findings

Richness of Information Sources

Tables 6.7 and 6.8 present the richness of information sources for different contingent situations. In considering the external contingent situations, two information types show significant differences among different market situations in terms of the richness of information sources used during NPD. For market and supplier/component related information, NPD in a turbulent market situation seems to access more information sources than those in a stable market situation.

While considering the internal contingent situations, the statistical results reveal significant differences among task types in terms of the use of information sources. All information types are significant in at least $P < 0.05$ level for the ANOVA or Duncan tests. Overall, Hard-to-Produce Radicals seem to utilize more information sources than other NPD types for most information types except customer-related information and manufacturing-related information. On the contrary, Easy-to-Produce Radicals seem to use fewer information sources than the other task types for most information types except the goal/strategy related information. Untried Incrementals seem to use more sources for acquiring technology/science and manufacturing related

Table 6.7 External Contingent Situations and the Richness of Information Sources

Information Types	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
Market Related Information	2.3333 (a) (1.0515)	2.2500 (.9670)	1.7586 (.9876)	NS (d)	(1) > (3) (c)
Supplier, Component Related Information	2.0000 (.7651)	1.5714 (.8789)	1.3448 (1.1109)	4.7657*	(1) > (3)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of information source richness. Sources Richness is measured by the number of different source types which were subjectively pointed by the interviewee and were regared as significant to the project.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (1) > (3) denotes that the mean of group (1) is significantly larger than the mean of group (3), based on P<.05 level.
(d) * P<.05, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 6.8 Internal Contingent Situations and the Richness of Information Sources

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Goal/Strategy Related Information	2.1304 (a) (.6944)	2.3500 (.8127)	1.8571 (1.0789)	1.5357 (1.1380)	3.1661* (d)	(4) < (1), (2) (c)
Market Related Information	1.7391 (1.1369)	2.4500 (.9987)	2.1786 (1.0203)	2.2143 (.9172)	NS	(2) > (1)
Regulation, Law, and Industrial Standard	1.0870 (.7332)	1.7000 (.8013)	1.1071 (.6853)	.8214 (.6118)	6.2292***	(2) > (1), (3), (4)
Supplier, Component Related Information	1.0000 (1.0000)	2.5000 (.8885)	1.4643 (.6929)	1.8929 (.6289)	13.9162***	(2) > (1), (3), (4) (4) > (1), (3) (3) > (1)
Competitor Related Information	1.8696 (1.1403)	2.6500 (.8127)	2.1071 (1.2864)	1.7857 (1.3705)	NS	(2) > (1), (4)
Customer Related Information	.8261 (1.3366)	.4000 (.8826)	.5714 (1.1031)	1.7500 (1.2360)	6.9882***	(4) > (1), (2), (3)
Cost/Price Related Information	2.2174 (.7952)	3.0500 (.9445)	2.2500 (1.2360)	2.8929 (.7373)	4.8266**	(2) > (1), (3) (4) > (1), (3)
Product Related Information	2.3913 (.7223)	3.0000 (.8584)	2.5000 (.7935)	2.7143 (.8545)	NS	(2) > (1), (3)
Technology / Science Related Information	2.2174 (1.1661)	3.0500 (.8870)	2.5714 (1.0338)	1.7500 (.9670)	6.9291***	(2) > (1), (4) (3) > (4)
Manufacturing Related Information	.6957 (.8221)	.9000 (.5525)	1.1429 (.5245)	1.4286 (.5727)	6.4693***	(4) > (1), (2) (3) > (1)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of information source richness. Sources Richness is measured by the number of different source types which were subjectively pointed by the interviewee and were regared as significant to the project.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (4) < (1), (2) denotes that the mean of group (4) is significantly smaller than the means of group (1) and group (2), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

information than others. Tried and Tested Incrementals tend to use more sources for supplier/ component, customer, cost/price, and manufacturing related information than other NPD types.

Bounded versus Unbounded Information Sources

Both external and internal contingent situations have little effect upon the selection of bounded or unbounded information sources during NPD. However, for competitor and technology/science related information, different types of NPD present different tendencies in using bounded or unbounded information sources (Table 6.9). For competitor related information, although all task types reveal a need for using more unbounded sources, the Tried and Tested Incrementals seem to have higher confidence about their previous experiences and therefore utilize more internal judgements than other NPD types. For technology/science related information, it is clear that most NPD should utilize their internal capability for developing new products. However, the Hard-to-Produce Radicals and the Untried Incrementals seem to be dissatisfied with their existing knowledge and therefore require more external technology/science related information than those of other types of NPD.

Primary versus Secondary Information Sources

Table 6.9 Internal Contingent Situations and the Use of Bounded or Unbounded Information Sources

Information Type	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)		
Competitor Related Information	8.8947 (a) (.3153) n=19	8.2105 (.9763) n=19	8.9167 (.4082) n=24	7.4176 (2.9915) n=24	4.1376** (d)	(4) < (1), (3) (c)
Technology/Science Related Information	2.4783 (1.6200) n=23	3.8500 (1.5313) n=20	3.8571 (1.8800) n=28	1.6429 (1.3113) n=28	11.9373***	(3) > (1), (4) (2) > (1), (4)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of whether the information was acqured from bounded or unbounded sources. Bounded information is defined as the information acquired from within the boundary of organisation while the unbounded one is that acquired from outside the company. Index for measuring the extent of using bounded or unbounded sources is calculated by the percentage of unbounded sources over total number of sources. While transfer to 1 to 9 scale, 1 denotes that all information were from inside the company; 9 denotes that all information were from outside the company.

(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.

(c) (4) < (1), (3) denotes that the mean of group (4) is significantly smaller than the means of group (1) and group (3), based on P< 05 level.

(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 6.10 Internal Contingent Situations and the Use of Primary or Secondary Information Sources

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals	(2) Hard-to-Produce Radicals	(3) Untried Incrementals	(4) Tried & Tested Incrementals	F	Duncan Results*
Supplier, Component Related Information	4.2308 (a) (2.3859) n=13	5.3000 (2.4730) n=20	3.1429 (2.5490) n=28	5.9643 (2.3016) n=28	6.9092*** (d)	(4) > (1), (3) (2) > (3)
Customer Related Information	3.2500 (1.6690) n=8	1.0000 (.0000) n=4	5.0000 (2.8284) n=6	3.2174 (2.4113) n=23	NS	(3) > (2) (c)
Technology / Science Related Information	3.1739 (1.5855) n=23	3.2500 (1.4824) n=20	3.5357 (1.7101) n=28	5.1786 (2.8291) n=28	5.6444**	(4) > (1), (2), (3)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of whether the information was acquired from primary or secondary sources. Primary information is defined as the information acquired from first-hand study or direct interaction with the informants during NPD. This may include studies, surveys, direct interactions, meetings, or personal intuition. Secondary information, on the contrary, is defined as the information that was acquired with no direct interaction with the informants, e.g., documentation, official document circulation, or indirect observations. Score for measuring the extent of using primary or secondary sources is calculated by the percentage of secondary sources over total number of sources. While transfer to 1 to 9 scale, 1 denotes that information was only from primary sources; 9 denotes that all information was only from secondary sources.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (3) > (2) denotes that the mean of group (3) is significantly larger than the mean of group (2), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

There is little difference in the use of primary or secondary information sources, whatever the NPD types or the external market conditions. However, similar to the use of bounded or unbounded sources, to some extent task types do influence the selection of primary or secondary information sources during NPD (Table 6.10). The Tried and Tested Incrementals seem to rely greatly on secondary information rather than other NPD types in terms of supplier/component and technology/science related information. On the contrary, the Easy-to-Produce Radicals and the Untried Incrementals show a tendency to acquire more primary information than other task types in terms of these two types of information. Finally, for most NPD the acquisition of customer related information tends to be primary rather than secondary. However, the Untried Incrementals seem to rely more on using secondary customer-related information.

Formal versus Informal Information Sources

Tables 6.11 and 6.12 show that both external and internal factors influence the selection of formal versus informal information sources. NPD under turbulent market conditions tends to use more formal sources for acquiring customer related information and more informal sources for goal/strategy related information than those under a stable market. Easy-to-Produce Radicals tend to use more formal sources for market related information, and more informal sources for

Table 6.11 External Contingent Situations and the Use of Formal or Informal Information Sources

Information Type	Environmental Situations (b) (1) Turbulent Market	(2) Declining Market	(3) Stable Market	F	Duncan Results*
Goal/Strategy Related Information	7.5405 (a) (2.2434) n=37	7.2308 (2.6729) n=26	5.7692 (2.4051) n=26	4.3625* (d)	(3) < (1), (2)
Customer Related Information	5.8947 (2.5150) n=19	7.2143 (2.1901) n=14	8.2500 (1.4880) n=8	3.4482*	(3) > (1) (c)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of whether the information was acquired from formal or informal sources. Formal information source is defined as the information acquired through formalized channels during NPD. Such information sources may include formal studies, surveys, meetings, documentation, or official document circulation. Informal source is defined as the information acquired through informal channels during NPD, e.g., direct interactions, personal intuition, or indirect observation. Index for measuring the type of information source thus is calculated by perceptage of formal sources been used. While transfer to 1 to 9 scale, 1 denotes that all the information was from formal sources; 9 denotes all the information was acquired from informal sources. The cases that did not acquire the particular information during NPD (i.e., the number of source is 0) were treated as system missing.

(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.

(c) (3) > (1) denotes that the mean of group (3) is significantly larger than the mean of group (1), based on P<.05 level.

(d) * P < .05, All Duncan results are based on P<.05 comparison.

Table 6.12 Internal Contingent Situations and the Use of Formal or Informal Information Sources

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals	(2) Hard-to-Produce Radicals	(3) Untried Incrementals	(4) Tried & Tested Incrementals	F	Duncan Results*
Market Related Information	5.0000 (a) (2.5820) n=19	4.6316 (2.2413) n=19	7.0385 (2.3751) n=26	5.1481 (2.3485) n=27	4.9073** (d)	(3) > (1), (2), (4)
Regulation, Law, and Industrial Standard	2.1111 (1.8436) n=18	1.7000 (1.3416) n=20	1.4167 (1.1765) n=24	1.1739 (.8341) n=23	NS	(1) > (4) (c)
Customer Related Information	8.5000 (1.4142) n=8	6.0000 (2.0000) n=4	8.1667 (.9832) n=6	6.0000 (2.5590) n=23	3.6391*	(4) < (1), (3)
Technology / Science Related Information	1.6087 (1.4690) n=23	1.5500 (.9445) n=20	1.9286 (1.3032) n=28	1.0714 (.3780) n=28	2.9085*	(3) > (4)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of whether the information was acquired from formal or informal sources. Formal information source is defined as the information acquired through formalized channels during NPD. Such information sources may include formal studies, surveys, meetings, documentation, or official document circulation. Informal source is defined as the information acquired through informal channels during NPD, e.g., direct interactions, personal intuition, or indirect observation. Index for measuring the type of information source thus is calculated by perceptage of formal sources been used. While transfer to 1 to 9 scale, 1 denotes that all the information was from formal sources; 9 denotes all the information was acquired from informal sources. The cases that did not acquire the particular information during NPD (i.e., the number of source is 0) were treated as system missing.

(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.

(c) (1) > (4) denotes that the mean of group (1) is significantly larger than the mean of group (4), based on P<.05 level.

(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

regulation, law, industrial standard, and customer related information than other NPD types. Hard-to-Produce Radicals tend to acquire market related information from formal sources. Untried Incrementals seem to use more informal sources for market, customer, and technology/science related information than other types of NPD. Tried and Tested Incrementals tend to use more formal sources than others for market, regulation, law, industrial standard, customer, and technology/science related information.

Summary

Statistical evidence suggests that both external and internal contingent factors influence the use of information sources during NPD. This is especially significant when considering internal contingent factors. Firms seem to employ quite a different mode of information acquisition for different task types, in terms of the number of information sources used, and the use of formal or informal sources. Hypothesis 2.4 is partially confirmed while hypothesis 2.3 is strongly supported.

Discussions

NPD under a turbulent market tends to use more sources for acquiring market and supplier/component related information than those under a stable market. This may be due to the fact that firms in a turbulent market often encounter a higher level of "equivocality" and therefore require a richer mode of information sources rather than the amount of information (Daft and Macintosh, 1981; Daft and Weick, 1984; Daft and Lengel, 1986). However, comparing this result with the findings in Section 6.2, little difference can be identified in terms of information acquisition activities under "uncertainty" and "equivocality" as proposed by Daft and his colleagues. "Uncertainty" and "equivocality" may not be easily and practically differentiated in the real-world situation. NPD in a turbulent market may encounter high levels of both "uncertainty" and "equivocality" simultaneously and therefore require both a higher "amount" of information as well as higher "richness" of information sources.

The selection of information sources is also influenced by the nature of projects. Compared to other NPD types, Easy-to-Produce Radicals seem to acquire all types of information in a less rich way (i.e., use fewer source types), except for goal/strategy related information. They also tend to use more internal and primary sources for acquiring technology/science related information, and use more formal sources for acquiring market related information. Discussion about information requirements of this NPD type (see Section 6.2) provides insight into the above observation. As Easy-to-Produce Radicals tend to encounter high uncertainty at the beginning of the NPD project but face little difficulty with manufacturing later in the process, they draw goal/strategy related information from richer sources to clarify initial project ambiguity so as to achieve better project planning. In addition, as the technology used by this type of NPD is often very radical, firms need to concentrate on in-house technological research/development. The current study observed that for Easy-to-Produce Radicals, the more radical the project, the higher the level of isolation of the project team from its external world. This finding does not support the theoretical assertion of Brown and Karagozoglu (1989) that radical innovation should emphasise the acquisition of external technology related information. Finally, focus on internal technological development also leads this NPD type to acquire other information in a less rich mode. For example, formal sources such as trade reports or published market surveys may be the major sources for this NPD type to acquire market related information.

Hard-to-Produce Radicals are keen to acquire NPD information (Section 6.2). They need to invest heavily in prototyping and manufacturing and in the mean time closely keep track of the advancement of technology and the changing market during a long development cycle. To reduce the financial risk from project failure, they tend to acquire most types of information (i.e., goal/strategy, market, regulation, law, industrial standard, supplier/component, competitor, cost/price, product, technology) from richer sources. This supports the view of Hauptman (1986), Ito and Peterson (1986), and Keller (1994), that nonroutine tasks, or very difficult projects, make a greater demand on information processing. Hard-to-Produce Radicals also tend to access more primary and unbounded technology related information than other NPD types. However, this is not the case of Easy-to-Produce Radicals. This suggests that the assertion of Brown and Karagozoglu (1989) that radical innovation should emphasise the acquisition of external technology related information may be valid only for Hard-to-Produce Radicals.

Untried Incrementals are low novelty products that are unfamiliar to the firm. They are often existing successful products in other market segments but may be new to the focal market. As a result, knowledge about product technology and manufacturing process is important to the development of this product type, while market and customer related information are less critical. Therefore, developers of Untried Incrementals tend to acquire technology/science and manufacturing related information from informal and richer sources, while acquiring customer, market related information from less rich sources. This partially confirms the observation of Holland et al. (1976) that while there is high uncertainty about the unfamiliar technology to be employed in a NPD, firms tend to rely on a more direct, informal, and rich information transmission.

Tried and Tested Incrementals are minor improvements to current products aimed at fulfilling customers' existing needs. Technology employed by this product type is relatively simple, while competition in the marketplace is high. As a result, their major considerations for strategic competition are capability in cost-leadership, speed to market, and final product quality. These considerations reflect on the use of information acquisition strategy, that the supplier/component, cost/price, manufacturing, and customer related information are highly important for this product type. They tend to acquire these four types of information from more sources than other NPD. However, the incremental nature of this product type gives it a less important position in corporate strategic planning. Meanwhile the developers of Tried and Tested Incrementals are familiar with current regulation, law, industrial standard, and technology applied in the product design. They also are well informed about competitors in the current market. Therefore they tend to rely on less rich or bounded sources for acquiring these types of information. The assertion by Keller (1994) that routine tasks do not need much information processing may only partially reflect the truth. This study suggests that Tried and Tested Incrementals are keen to acquire supplier/component, cost/price, manufacturing, and customer related information from many sources. The need for information and characteristics of information acquisition may depend upon both task and information type.

§6.4 The Key Players in NPD Information Acquisition under Contingent Situations

Hypothesis 2.3: *For successful NPD, the key players in information acquisition vary significantly with the type of new product project undertaken.*

Hypothesis 2.4: *For successful NPD, the key players in information acquisition vary significantly with the dynamics of its incumbent marketplace.*

The information acquisition behaviour under NPD contingent situations is also examined in terms of the key players during acquisition activities. Key players are assessed by the probability (between zero and one) of a person or functional department mentioned by the interviewee playing a key role in acquiring and transmitting the proposed ten types of information during NPD. To calculate such probability, the frequency with which each player acquired and transmitted information was counted. The frequency with which a specific player acquired information is then divided by the total frequency of all players. The resultant percentage therefore is the weight (or impact) of the specific player in the information acquisition activities.

Key Findings

Based on in-depth interviews, four types of key players were identified, i.e., the CEO/ Executive Board, R&D, Marketing, and the Project Committee. Tables 6.13 and 6.14 present the probability of these four groups of people dominating NPD information acquisition under external and internal contingent situations. Among all groups of people, R&D, surely, is the major party responsible for NPD information acquisition. There is no evidence to suggest that CEO/Executive Board, Marketing, or the Project Committee will adjust the extent of involvement in NPD information acquisition according to different external project situations/conditions. However, in a declining market, R&D seems to have less influence upon NPD information acquisition than in other situations. Research hypothesis 2.4 is partially supported.

Departing from external contingent situations, the statistical results suggest that internal contingent situations have strong influences upon the role of functional departments in acquiring NPD information. The CEO/Executive Board shows a higher level of participation in information acquisition while developing Easy-to-Produce Radicals. R&D seems to have a higher level of

Table 6.13 External Contingent Situations and Key Players in Information Acquisition

Key Players	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
CEO/Executive Board	.0740 (a) (.1163)	.0960 (.1705)	.0930 (.1124)	NS (d)	
R&D	.5263 (.1739)	.4468 (.1570)	.5226 (.1090)	NS	(1) > (2) (c)
Marketing	.2679 (.1434)	.3073 (.1863)	.2852 (.1454)	NS	
Project Committee	.1318 (.1218)	.1498 (.1211)	.0992 (.1008)	NS	

(a) Group mean and standard deviation (in parentheses) are based on the extent of involvement of key players in NPD information processing. Key Player is measured by the probability (between 0 to 1) of a person or department who played a key role in acquiring and transmitting the proposed ten types of information during NPD. To calculate such probability, firstly the frequency for each player in acquiring and transmitting information was counted. Then the frequency is divided by the that of all departments and hence a percentage can be defined.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (1) > (2) denotes that the mean of group (1) is significantly larger than the mean of group (2), based on P<.05 level.
(d) * P < .05, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 6.14 Internal Contingent Situations and Key Players in Information Acquisition

Key Players	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
CEO/Executive Board	.1587 (a) (.1643)	.0396 (.0554)	.1014 (.1593)	.0413 (.0691)	4.9079** (d)	(1) > (2), (4) (c)
R&D	.5056 (.1552)	.5226 (.1571)	.5663 (.1567)	.4246 (.1283)	4.3898**	(4) < (2), (3)
Marketing	.2427 (.1787)	.2751 (.1239)	.2434 (.1529)	.3658 (.1361)	4.0511**	(4) > (1), (2), (3)
Project Committee	.0930 (.1056)	.1626 (.0997)	.0889 (.1061)	.1688 (.1286)	3.7872*	(4) > (1), (3) (2) > (1), (3)

(a) Group mean and standard deviation (in parentheses) are based on the extent of involvement of key players in NPD information processing. Key Player is measured by the probability (between 0 to 1) of a person or department who played a key role in acquiring and transmitting the proposed ten types of information during NPD. To calculate such probability, firstly the frequency for each player in acquiring and transmitting information was counted. Then the frequency is divided by the that of all departments and hence a percentage can be defined.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (1) > (2), (4) denotes that the mean of group (1) is significantly larger than the means of group (2) and group (4), based on P<.05 level.
(d) * P < .05, ** P < .01, NS: Not Significant. All Duncan results are based on P<.05 comparison.

authority while developing Untried Incrementals and Hard-to-Produce Radicals, and is less active while developing Tried and Tested Incrementals. The Marketing function seems to be highly active in NPD information acquisition while developing Tried and Tested Incrementals. The Project Committee shows a higher usefulness in information acquisition when the NPD are Hard-to-Produce Radicals or Tried and Tested Incrementals, as opposed to Easy-to-Produce Radicals and Untried Incrementals. Hypothesis 2.3 is strongly supported.

Discussions

Statistical results suggest that the use of key players for NPD information processing is highly associated with the information requirements of the particular project. Easy-to-Produce Radicals tend to be highly uncertain at the beginning of the development cycle, but face little difficulty with manufacturing later in the process. For this NPD type, it is necessary for CEO/ Executive Board to spend more effort becoming involved in the project so as to better define project goals and formulate NPD strategic planning. CEO/Executive Board therefore shows a deeper involvement in developing Easy-to-Produce Radicals.

Similarly, R&D is the key player in NPD information processing when product design and technology are more difficult or unfamiliar to the firm (i.e., Hard-to-Produce Radicals and Untried Incrementals). R&D-dominated information processing provides the best opportunity to acquire technology-related information of the highest quality to suit the technicians' needs.

Marketing function is important in NPD when the project requires a deeper understanding of customers' current needs. Tried and Tested Incrementals tend to encounter higher pressure in market competition because of the similarity in products of this type. It is not surprising that marketing function becomes involved more deeply in developing Tried and Tested Incrementals to provide up-to-date information about customers.

Project committee is more important for NPD information acquisition when the project needs multi-discipline knowledge to smooth the development process. Hard-to-Produce Radicals are often difficult in both product technology and manufacturing; this triggers the need to "design for manufacturing". They also need to monitor market trends because the product development cycle tends to be long; this calls for interaction between R&D and marketing. On the other hand, Untried Incrementals have less knowledge about the product class. There is a need for this product type to create more information channels to access unfamiliar knowledge. Project committee contributes to both product types by providing richer information from more sources.

These observations confirm the assertion of Workman (1993) that the level of marketing intervention during NPD is subject to the task type. As he suggested, marketing function may be active in developing low-end consumer products; however, for high-tech ones, R&D is the major player.

§6.5 The Timing of NPD Information Acquisition under Contingent Situations

Hypothesis 2.5: *For successful NPD, the timing for information acquisition varies significantly with the type of new product project undertaken.*

Hypothesis 2.6: *For successful NPD, the timing for information acquisition varies significantly with the dynamics of its incumbent marketplace.*

The timing for NPD information acquisition is measured in terms of the NPD stage at which the firm started to acquire a specific type of information. Based on published surveys and the results of the exploratory study, the NPD stages (or phases) are pre-defined as the: (1) strategy development stage, (2) idea generation stage, (3) preliminary assessment stage, (4) concept development stage, (5) prototyping stage, (6) trial/test stage, and (7) commercialisation stage. As not all information types have actually been acquired during the development process of all NPD, only those which have acquired information during product development are incorporated in the analyses. In addition, as this section is aimed at revealing the "timing" of information acquisition during NPD, only acquisition activities occurring during the development cycle are investigated. Information acquisition that was based on regular scanning or transferred from other projects is therefore treated as system missing. As a result, the sample size for each treatment is very significantly reduced. However, as explained in the last section, the employment of Duncan Multiple Range Test overcomes the problem of interpretation based on a small sample[2].

Key Findings

For three information types, external contingent situations show significant impacts upon the timing of NPD information acquisition (Table 6.15). NPD in a declining market situation tend to acquire goal/strategy and customer related information much earlier than those under other market situations. Hypothesis 2.6 is supported. Internal contingent factors also influence the timing of NPD information acquisition (Table 6.16). Compared with other NPD types, Easy-to-Produce Radicals tend to acquire supplier/component, cost/price, and manufacturing related information in the later stages of NPD. Hard-to-Produce Radicals tend to acquire cost/ price related information earlier than other types of NPD, but later for manufacturing related information. Untried Incrementals seem to acquire supplier/component and competitor related information earlier than others, but acquire cost/price and manufacturing related information later. Finally, Tried and Tested Incrementals tend to acquire supplier/component, cost/price, and manufacturing related information much earlier than other types of NPD, while acquiring competitor related information later. Hypothesis 2.5 is also supported.

Discussions

The early acquisition of goal/strategy and customer related information for firms under a declining market echoes the findings of More (1984). More reported that while perceived uncertainty about competition and consumer behaviour is high, firms tend to conduct market research much earlier during the new product development cycle. In the declining market firms may have a stronger fear about losing customers, i.e., they may feel a higher uncertainty about the marketplace. As a result, they need to acquire customer related information earlier. On the other hand, in a turbulent market, NPD seems to acquire information much later. Because the marketplace is so dynamic, firms may have no time to conduct market survey. The better timing for understanding marketplace may be at the later stages of NPD.

NPD types also influence the timing of information acquisition. In general, the timing for acquiring a specific type of information is decided by the needs of the particular project for this information. If a specific type of information is perceived as highly urgent/critical to the project,

Table 6.15 External Contingent Situations and the Timing for Starting Information Acquisition

Information Type	Environmental Situations (b)			F	Duncan Results*
	(1) Turbulent Market	(2) Declining Market	(3) Stable Market		
Goal/Strategy Related Information	1.2609 (a) (.6887) n=23	1.0000 (.0000) n=21	1.0000 (.0000) n=21	NS (d)	(1) > (2), (3) (c)
Competitor Related Information	2.6364 (1.5667) n=11	2.0000 (.9258) n=15	1.3750 (.7440) n=8	NS	(1) > (3)
Customer Related Information	3.3636 (1.2060) n=11	2.2222 (1.0929) n=9	2.0000 (.8165) n=4	3.5632*	(1) > (2)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of the phase (timing) in which NPD started to acquire a specific type of information. Only those who have acquired information during NPD are counted. Information which was scanned regularly or acquired from other previous projects is treated as system missing. The scales: 1 = Strategy Development Stage; 2 = Idea Generation Stage; 3 = Preliminary Assessment Stage; 4 = Concept Development Stage; 5 = Prototyping Stage; 6 = Trial/Test Stage; 7 = Commercialisation Stage.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (1) > (2), (3) denotes that the mean of group (1) is significantly larger than the means of group (2) and group (3), based on P<.05 level.
(d) * P < .05, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 6.16 Internal Contingent Situations and the Timing for Starting Information Acquisition

Information Type	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals	(2) Hard-to-Produce Radicals	(3) Untried Incrementals	(4) Tried & Tested Incrementals		
Supplier, Component Related Information	4.3333 (a) (1.0328) n=6	3.6667 (.8165) n=6	3.2143 (.9750) n=14	3.1250 (.9910) n=8	NS (d)	(1) > (3), (4) (c)
Competitor Related Information	2.0000 (.8944) n=6	1.8000 (1.0954) n=5	1.6000 (.7368) n=15	3.1250 (1.6421) n=8	3.5740*	(4) > (3)
Cost/Price Related Information	4.7222 (1.9646) n=18	3.3333 (1.4951) n=18	4.2273 (2.0915) n=22	3.0800 (1.5524) n=25	3.7635*	(1) > (2), (4) (3) > (4)
Manufacturing Related Information	5.0000 (1.4142) n=10	5.7143 (.8254) n=14	5.5417 (.8836) n=24	3.8667 (1.4075) n=15	8.9131***	(4) < (1), (2), (3)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of the phase (timing) in which NPD started to acquire a specific type of information. Only those who have acquired information during NPD are counted. Information which was scanned regularly or acquired from other previous projects is treated as system missing. The scales: 1 = Strategy Development Stage; 2 = Idea Generation Stage; 3 = Preliminary Assessment Stage; 4 = Concept Development Stage; 5 = Prototyping Stage; 6 = Trial/Test Stage; 7 = Commercialisation Stage.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (1) > (3), (4) denotes that the mean of group (1) is significantly larger than the means of group (3) and group (4), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

firms tend to acquire this information much earlier. On the other hand, while a specific type of information is regarded as less important, it may be acquired at the later stages of NPD. However, the above observation does not apply to Untried Incrementals. Untried Incrementals tend to have an early acquisition of supplier/component and competitor related information, although these types of information do not show specific importance to this NPD type. This may be due to the exclusive nature of Untried Incrementals. As this NPD type is often the imitation or modification of existing products offered in other market segments (especially in foreign markets), clearly new product developers should have early access to supplier/component and competitor related information during NPD. They should have knowledge of the original supplier/manufacturer as well as the potential competitors. They also need to know whether the supply of key components for this NPD is available locally. Without such initial understanding, the development of Untried Incrementals would be impossible.

§6.6 Summary of NPD Information Acquisition under Contingencies

This chapter examines NPD information acquisition behaviour under external and internal contingent situations. Overall, statistical results suggest that internal contingent situations (i.e., the task types) are better predictors of NPD information acquisition behaviour than external contingent situations (i.e., market situations). Table 6.17 is a summary of information acquisition behaviour of firms under NPD contingencies in terms of the proposed ten information types.

Table 6.17 Summary of Information Acquisition Behaviours under NPD Contingent Situations

Information Acquisition Behaviour	Mean	External Contingencies			Internal Contingencies			
		Turbulent Market	Declining Market	Stable Market	Easy-making Radicals	Hard-producing Radicals	Inexperienced Incrementals	Proficient Incrementals
Goal/Strategy Related Information								
Necessity of Information (scale: 1-9)	6.1010				V. High	High	Moderate	Moderate
Acquire or Not Acquire (scale: 0-2)	1.6970				Exclusive	Exclusive	Exclusive	Regular
Period Spent in Acquisition (phases)	.9697							
Richness of Sources (No. of types)	1.9293				Rich	Rich	Rich	Less Rich
Bounded or Unbounded (scale: 1-9)	4.2247							
Primary or Secondary (scale: 1-9)	3.3371							
Formal or Informal (scale: 1-9)	6.9326	Informal	Informal	Moderate				
Timing for Acquisition (scale: 1-7)	1.0923	Later	Earlier	Earlier				
Market Related Information								
Necessity of Information (scale: 1-9)	5.9293	High	Moderate	Low	Low	V. High	Moderate	Moderate
Acquire or Not Acquire (scale: 0-2)	1.4848							
Period Spent in Acquisition (phases)	.7273				V. Short	Short	Moderate	Moderate
Richness of Sources (No. of types)	2.1414	Rich	Rich	Less Rich	Less Rich	Highly Rich	Rich	Rich
Bounded or Unbounded (scale: 1-9)	7.7363							
Primary or Secondary (scale: 1-9)	6.9560							
Formal or Informal (scale: 1-9)	5.5495				Moderate	Moderate	Informal	Moderate
Timing for Acquisition (scale: 1-7)	1.6207							
Regulation, Law, and Industrial Standard								
Necessity of Information (scale: 1-9)	3.6768				Low	Moderate	Low	V. Low
Acquire or Not Acquire (scale: 0-2)	1.1010				Regular	Exclusive	Regular	Occasional
Period Spent in Acquisition (phases)	.3535							
Richness of Sources (No. of types)	1.1414				Destitute	Less Rich	Destitute	Destitute
Bounded or Unbounded (scale: 1-9)	4.3882							
Primary or Secondary (scale: 1-9)	8.6941							
Formal or Informal (scale: 1-9)	1.5647				Less Formal	V. Formal	V. Formal	V. Formal
Timing for Acquisition (scale: 1-7)	2.2500							
Supplier/Component Related Information								
Necessity of Information (scale: 1-9)	5.0101	High	Moderate	Low	V. Low	V. High	Moderate	Moderate
Acquire or Not Acquire (scale: 0-2)	1.4545				Occasional	Exclusive	Exclusive	Exclusive
Period Spent in Acquisition (phases)	.8788				V. Short	Moderate	Moderate	Moderate
Richness of Sources (No. of types)	1.6869	Rich	Less Rich	Destitute	Destitute	Highly Rich	Less Rich	Rich
Bounded or Unbounded (scale: 1-9)	5.8202							
Primary or Secondary (scale: 1-9)	4.6742				Moderate	Moderate	Primary	Secondary
Formal or Informal (scale: 1-9)	3.8652							
Timing for Acquisition (scale: 1-7)	3.4706				Later	Later	Earlier	Earlier
Competitor Related Information								
Necessity of Information (scale: 1-9)	4.7071							
Acquire or Not Acquire (scale: 0-2)	1.3535	Regular	Exclusive	Regular				
Period Spent in Acquisition (phases)	.7273	Short	Moderate	Short	Short	V. Short	Moderate	Short
Richness of Sources (No. of types)	2.0707				Rich	Highly Rich	Rich	Less Rich
Bounded or Unbounded (scale: 1-9)	8.3372				Unbounded	Unbounded	Unbounded	Moderate
Primary or Secondary (scale: 1-9)	7.7791							
Formal or Informal (scale: 1-9)	4.5930							
Timing for Acquisition (scale: 1-7)	2.0588	Later	Moderate	Earlier	Moderate	Moderate	Earlier	Later

Table 6.17 (Continued)

Information Acquisition Behaviour	Mean	External Contingencies			Internal Contingencies			
		Turbulent Market	Declining Market	Stable Market	Easy-making Radicals	Hard-producing Radicals	Inexperienced Incrementals	Proficient Incrementals
Customer Related Information								
Necessity of Information (scale: 1-9)	3.8687				Low	V. Low	V. Low	V. High
Acquire or Not Acquire (scale: 0-2)	.7172				Occasional	Seldom	Seldom	Exclusive
Period Spent in Acquisition (phases)	.6364				Short	Short	V. Short	Long
Richness of Sources (No. of types)	.9293				Destitute	Destitute	Destitute	Less Rich
Bounded or Unbounded (scale: 1-9)	8.1220							
Primary or Secondary (scale: 1-9)	3.2683				Primary	H. Primary	Moderate	Primary
Formal or Informal (scale: 1-9)	6.8049	Moderate	Informal	Informal	Informal	Moderate	Informal	Moderate
Timing for Acquisition (scale: 1-7)	2.7083	Later	Earlier	Earlier				
Cost/Price Related Information								
Necessity of Information (scale: 1-9)	4.9495	High	Moderate	Low	Low	Moderate	Low	High
Acquire or Not Acquire (scale: 0-2)	1.9798							
Period Spent in Acquisition (phases)	1.4949				Long	V. Long	Long	V. Long
Richness of Sources (No. of types)	2.5859				Rich	Highly Rich	Rich	Highly Rich
Bounded or Unbounded (scale: 1-9)	5.0101							
Primary or Secondary (scale: 1-9)	4.4141							
Formal or Informal (scale: 1-9)	5.9798							
Timing for Acquisition (scale: 1-7)	3.7952				Later	Earlier	Latter	Earlier
Product Related Information								
Necessity of Information (scale: 1-9)	7.5657				V. High	V. High	V. High	Moderate
Acquire or Not Acquire (scale: 0-2)	1.9899							
Period Spent in Acquisition (phases)	1.7879							
Richness of Sources (No. of types)	2.6364				Rich	Highly Rich	Rich	Highly Rich
Bounded or Unbounded (scale: 1-9)	4.8788							
Primary or Secondary (scale: 1-9)	3.7374							
Formal or Informal (scale: 1-9)	3.9596							
Timing for Acquisition (scale: 1-7)	2.7045							
Technology/Science Related Information								
Necessity of Information (scale: 1-9)	7.1313				V. High	V. High	V. High	Moderate
Acquire or Not Acquire (scale: 0-2)	1.8384				Exclusive	Exclusive	Exclusive	Often
Period Spent in Acquisition (phases)	1.6162	Moderate	Long	V. Long	V. Long	Long	V. Long	Moderate
Richness of Sources (No. of types)	2.3535				Rich	Highly Rich	Highly Rich	Less Rich
Bounded or Unbounded (scale: 1-9)	2.9091				Bounded	Moderate	Moderate	Bounded
Primary or Secondary (scale: 1-9)	3.8586				Primary	Primary	Primary	Moderate
Formal or Informal (scale: 1-9)	1.5354				V. Formal	V. Formal	Formal	V. Formal
Timing for Acquisition (scale: 1-7)	3.9322							
Manufacturing Related Information								
Necessity of Information (scale: 1-9)	3.0303				V. Low	V. Low	V. Low	Moderate
Acquire or Not Acquire (scale: 0-2)	1.6263	Exculsive		Regular	Regular	Exclusive	Exclusive	Exclusive
Period Spent in Acquisition (phases)	1.1414				Moderate	Moderate	Long	Long
Richness of Sources (No. of types)	1.0707				Destitute	Destitute	Destitute	Less Rich
Bounded or Unbounded (scale: 1-9)	1.0988							
Primary or Secondary (scale: 1-9)	3.0247							
Formal or Informal (scale: 1-9)	2.2346							
Timing for Acquisition (scale: 1-7)	5.0952				Moderate	Later	Later	Earlier
Key Player in Acquisition								
CEO/Executive Board (probability)	.0852				more likely	less likely	moderate	less likely
R&D (probability)	.5033	more likely	less likely	moderate	moderate	more likely	more likely	less likely
Marketing (probability)	.2841				less likely	less likely	less likely	more likely
Project Committee (probaility)	.1274				less likely	more likely	less likely	more likely

Notes

1. Based on the NPD literature, the phases of new product development are defined as: (1) Strategy Development Stage, (2) Idea Generation Stage, (3) Preliminary Assessment Stage, (4) Concept Development, (5) Prototyping Stage, (6) Trial/Test Stage, and (7) Commercialisation Stage. The number of the above phases that were identified as having actually acquired a specific information for the particular project is therefore counted. The resultant number of phases is then used as a quasi-indicator for measuring the period spent in information acquisition.

2. Based on the Studentized Range Statistic, Duncan's Multiple Range Test makes pairwise comparisons using a stepwise order of comparisons identical to the order used by Student Newman Keuls Test, but set a protection level for the error rate for the collection of tests. The sample size of each group in the comparison is considered. According to the decision rule, the difference between two treatment means is significant when:

$$\left|\bar{T}_a - \bar{T}_b\right| \geq q \times r \times \sqrt{\frac{1}{n_a} + \frac{1}{n_b}}$$

Where T is the treatment mean of each group; q is the Studentized Range Statistic; r is the range of the treatment means; n is the sample size of each treatment. It is clear that the smaller the values of n_a and n_b, the less the significance of the difference between the means of two groups. For more detailed description about Duncan Test please refer to Chapter Four.

Chapter Seven

The Management of NPD Information Transmission

7

Subsequent to the investigation of NPD information acquisition behaviour in the last chapter, this chapter considers how firms deal with NPD information transmission under different situations. Based on the same contingency dimensions developed in Chapter Five, the ten information types that were discussed in the last chapter are examined. Three variables are employed to observe the phenomena of NPD information transmission, i.e., the extent of departmental coupling for NPD information transmission, the level of information redundancy during information transmission, and the kinds of communication channel used. ANOVA and Duncan results suggest that internal contingent situations (i.e., the NPD types) have a moderate impact upon the extent of departmental coupling and the level of information redundancy. They also have strong influence upon the selection of communication channels. However, external contingent situations have a lesser effect in determining NPD information transmission.

7 The Management of NPD Information Transmission

§7.1 Introduction

According to the conceptual framework discussed in Chapter three, the second stage of NPD information processing is the transmission process of acquired information, which can be described in terms of: (1) the managerial settings for departmental communication, (2) the organisational norm or attitude to information transmission, and (3) the selection of communication channels. By centring on these issues, this chapter explores NPD information transmission of firms under external and internal contingent situations. In this chapter, each of the ten information types discussed in the last chapter are further examined.

Management settings for departmental communication are represented by the level of departmental coupling during NPD. The higher the level of departmental coupling, the more the functional departments participated in NPD information processing. In the current study, departmental coupling is used to measure the width of managerial settings for NPD information transmission, while the depth of NPD communication is measured by the extent of information redundancy. Organisational norms or attitudes influence the state of information redundancy in organisation. Organisations that have a more open climate tend to allow a more redundant (or richer) mode of information transmission which takes into consideration more communication paths and more channel choices for transferring information. In addition to the above measures concerning the width and depth of NPD information transmission, the third dimension of measures looks into the quality of such communication, i.e., the selection of channel types. A variety of possible channel types for NPD communication was identified through in-depth interviews. These channel types however have been further categorised into direct/indirect and formal/informal channels, in an attempt to reveal the nature of channel selection under varying NPD conditions.

§7.2 Departmental Coupling and Contingent Situations

> ***Hypothesis 3.1:*** *For successful NPD, the extent of departmental coupling during product innovation varies significantly with the type of new product project undertaken.*
>
> ***Hypothesis 3.2:*** *For successful NPD, the extent of departmental coupling during product innovation varies significantly with the dynamics of its incumbent marketplace.*

Departmental coupling for NPD information transmission is measured by the number of different functional departments that have taken a significant part in acquiring or transmitting a particular type of information. Different functional areas such as R&D, Marketing, Manufacturing, Purchasing, Finance, and Service are considered. In addition, Top Management involvement is included in the assessment. Possible values for this measure ranged from zero (where no information was acquired and therefore no communication occurred during NPD) to seven (where all functional departments participated in information processing). A value of one suggests a "one man show" where only one functional department was primarily involved in the entire information processing process.

Key Findings

ANOVA and Duncan tests suggest that external contingent situations have no effect upon the level of departmental coupling for NPD information transmission. For internal contingent situations, only three out of ten information types are identified as showing significant differences in coupling level among new product types, i.e., supplier/component, customer, and manufacturing related information. Hypothesis 3.1 is partially supported while hypothesis 3.2 is rejected. Table 7.1 shows the differences of departmental coupling among new product types.

Discussions

In general, statistical results suggest a low departmental coupling during NPD for most Taiwanese firms. However, measurement of coupling may be altered by the fact that some types of information were not actually acquired during NPD. It was assumed that there was no functional coupling for a specific type of information (i.e., the rating of coupling is zero), when this information was not acquired during NPD. This may greatly reduce the observed aggregated

Table 7.1 Internal Contingent Situations and Departmental Coupling for NPD Information Transmission

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Supplier, Component Related Information	.6522 (a) (.6473)	1.4500 (.9987)	1.2857 (.4600)	1.3929 (.4973)	7.3384*** (d)	(1) < (2), (3), (4)
Customer Related Information	.6522 (1.0706)	.4000 (.8208)	.3571 (.7310)	1.1071 (.6853)	4.6202**	(4) > (2), (3) (c)
Manufacturing Related Information	.6522 (.8317)	.9500 (.6048)	1.2143 (.6299)	1.7143 (.7127)	10.5235**	(4) > (1), (2), (3) (3) > (1)

(a) Group Means and standard deviations (in parentheses) are based on the number of functional departments that participated in information processing during NPD. The scale ranges from 0 to 7 in which 0 denotes no information was acquired especially for the particular NPD and therefore no departmental communication was required, to 7 which denotes that all functional departments participated in NPD information processing.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test Comparisons.
(c) (4) > (2), (3) denotes that the mean of group (4) is significantly larger than the means of group (2) and group (3), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

level of departmental coupling. That is, the actual level of departmental coupling may be in effect higher than that suggested by the statistical results. However, the number denoting functional participation is still a good indicator for measuring departmental coupling. At least, this measure effectively reveals the relative level of coupling among different NPD types.

Previous researchers looking into the issue of functional coupling tend to centre on revealing the impact of functional coupling on project success (e.g., Olin, 1973; Van Der Meer and Calori, 1989). Although some scholars did suggest effective strategies for managing functional coupling, very often their discussions were limited to observations of general phenomena of functional communication without differentiating the level of coupling between different information types (e.g., Ansoff and Stewart, 1967; Levinson and Moran, 1987). The current study compares the extent of departmental coupling during NPD, based on both task types and information types. Statistical findings do not support the theoretical assertions of Ansoff and Stewart (1967) and Gupta et al. (1986) that radical innovations (or highly uncertain projects) require a higher level of functional coupling than incremental ones. Empirical results show that radical innovations seem to use a more inward/isolated mode for communication than that used by incremental ones. This seems to confirm the empirical studies by Allen et al. (1980) and Hauptman (1986). They reported that development projects, or routine tasks, tend to have a higher need of functional coordination and control, than do research projects, or nonroutine ones. They suggested that this is due to the trade-off between two types of communication, i.e., one for integration and coordination and the other for enhancing technological innovation.

With regard to supplier/component related information, Easy-to-Produce Radicals seem to be highly limited in departmental coupling during NPD. In comparison with the findings stated in Chapter Six, such a result may be due to the lack of acquisition of this information. As Easy-to-Produce Radicals often perceive supplier/component related information as less important, they tend not to acquire such information especially for a particular NPD, and therefore, lack motivation for departmental communication. With customer related information, among all groups, Tried and Tested Incrementals seem to present the highest departmental coupling during NPD. On the one hand, this may be due to the fact that Tried and Tested Incrementals are aimed at satisfying customers' current needs, which requires R&D to keep track with their customers. On the other, they also need to pursue cost-leadership strategy so as to maintain their competitive advantage. As a result, a higher coupling between R&D, marketing, and manufacturing is important. It is clear that the extent of information acquisition is positively associated with the level of departmental coupling. Finally, for manufacturing related information, as anticipated by the current study, the Incrementals (both the Untried and the Tried and Tested) show a greater extent of departmental coupling than those of radical NPD. As incremental innovations often encounter higher pressure of price competition than do the radicals, it is important for them to "design for manufacturing" and therefore maintain their competitive advantage through mass-production and cost-leadership.

§7.3 NPD Information Redundancy and Contingent Situations

> ***Hypothesis 3.3:*** *For successful NPD, the level of information redundancy during product innovation varies significantly with the type of new product project undertaken.*

> ***Hypothesis 3.4:*** *For successful NPD, the level of information redundancy during product innovation varies significantly with the dynamics of its incumbent marketplace.*

Two variables are employed to measure the level of information redundancy for NPD communication. The first variable examines the number of types of communication channel that

Figure 7.1 Some Examples of Channel Types for NPD Information Transmission

	Formal	Informal
Indirect	memos MIS official document circulation documentation	video/audio tapes Fax/Telex mails
	eMail	
Direct	meetings electronic meetings seminars electronic groupwares	participation interaction face-to-face discussion

Source: the current study.

were used to transmit specific information for a particular NPD. The more the channel types used simultaneously during NPD, the higher the redundancy of information transmission. Figure 7.1 provides some examples of channel types for NPD information transmission. The second variable counts the number of significant communication paths (i.e., information flows) among functional departments which appeared during NPD. Relatively, the greater the number of communication paths, the higher the redundancy of information in NPD communication. However, it is also possible that NPD did not acquire specific information during the development process. In such a case no departmental communication can be identified and, therefore, the value of measuring information redundancy is zero.

Key Findings

Tables 7.2 to 7.5 show how information redundancy for NPD communication can vary according to different project situations. As discussed above, two variables are used to measure information redundancy: (1) the number of different channel types used in NPD (Tables 7.2 and 7.4), and (2) the number of information flows appearing during NPD (Tables 7.3 and 7.5). In general, the level of information redundancy varied according to the nature of the external market for three out of ten information types (Tables 7.2 and 7.3). Hypothesis 3.4 is partially supported. Tables 7.4 and 7.5 present the impact of internal contingent situations upon information redundancy. For eight out of ten information types, the extent of information redundancy tends to differ according to different task types. Hypothesis 3.3 is supported.

Discussions

Table 7.2 External Contingent Situations and the Redundancy of Information Transmission: Impact of the Number of Different Channel Types

Information Type	Environmental Situations (b)			F	Duncan Results*
	(1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)		
Supplier, Component Related Information	1.2381 (a) (.4311)	.9643 (.5079)	.8621 (.5158)	5.9170** (d)	(1) > (2), (3)
Customer Related Information	.5000 (.5947)	.7500 (.8444)	.2759 (.4549)	3.8897*	(2) > (3) (c)
Product Related Information	1.2381 (.4844)	1.2143 (.4179)	1.0345 (.1857)	NS	(1) > (3)

(a) Group mean and standard deviation (in parentheses) are based on the absolute number of different types of communication channels which were subjectively pointed by the interviewee and were regarded as significant to the project. The minimum number of channel types used for a NPD is zero when no information was acquired. However, there is no maximum number for this indicator because different information types may have different sets of communication channels. This indicator does not intend to interpret the differences of information redundancy between information types; rather, it is aimed at comparing the differences between different contingent situations.
(b) (1), (2), and (3) are group identification numbers for Duncan Test Comparisons.
(c) (2) > (3) denotes that the mean of group (2) is significantly larger than the mean of group (3), based on P<.05 level.
(d) * P < .05, ** P < .01, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 7.3 External Contingent Situations and the Redundancy of Information Transmission: Impact of the Number of Information Flows

Information Type	Environmental Situations			F	Duncan Results*
	(1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)		
Supplier, Component Related Information	2.2619 (.9642)	2.0000 (1.2172)	1.5862 (1.4272)	NS	(1) > (3)
Customer Related Information	.8810 (1.1088)	2.2500 (2.9392)	.7931 (1.4238)	5.6075**	(2) > (1), (3)

(a) Group mean and standard deviation (in parentheses) are based on the absolute number of different information flows between functional departments which were subjectively pointed by the interviewee and were regarded as significant to the project. the minimum number of this indicator is zero when no information was acquired. However, there is no maximum number for this indicator because different information types may have different sets of communication channels. This indicator does not intend to interpret the differences of information redundancy between information types; rather, it is aimed at comparing the differences between different contingent situations.
(b) (1), (2), and (3) are group identification numbers for Duncan Test Comparisons.
(c) (1) > (3) denotes that the mean of group (1) is significantly larger than the mean of group (3), based on P<.05 level.
(d) * P < .05, ** P < .01, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 7.4 Task Types and the Redundancy of Information Transmission: Impact of the Number of Different Channel Types

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Goal/Strategy Related Information	1.0435 (a) (.2085)	1.1000 (.3078)	.8929 (.3150)	.8214 (.5480)	2.8183* (d)	(2) > (4) (c)
Supplier, Component Related Information	.6957 (.7029)	1.1500 (.3663)	1.1786 (.3900)	1.1429 (.3563)	5.7306**	(1) < (2), (3), (4)
Customer Related Information	.3913 (.5830)	.3000 (.6569)	.2500 (.5182)	1.0000 (.6086)	9.4430***	(4) > (1), (2), (3)
Manufacturing Related Information	.4783 (.5108)	.8000 (.4104)	.9643 (.3313)	1.1071 (.3150)	11.8098***	(1) < (2), (3), (4) (2) < (4)

(a) Group mean and standard deviation (in parentheses) are based on the absolute number of different types of communication channels which were subjectively pointed by the interviewee and were regarded as significant to the project. The minimum number of channel types used for a NPD is zero when no information was acquired. However, there is no maximum number for this indicator because different information types may have different sets of communication channels. This indicator does not intend to interpret the differences of information redundancy between information types; rather, it is aimed at comparing the differences between different contingent situations.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test Comparisons.
(c) (2) > (4) denotes that the mean of group (2) is significantly larger than the mean of group (4), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 7.5 Task Types and the Redundancy of Information Transmission: Impact of the Number of Information Flows

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Regulation, Law, and Industrial Standard	1.1739 (a) (.9841)	1.6500 (.7452)	1.1429 (.7052)	.9286 (.5394)	3.7027* (d)	(2) > (1), (3), (4)
Supplier, Component Related Information	1.1739 (1.2668)	2.7500 (1.2085)	1.8571 (1.0789)	2.2500 (.8444)	8.1460***	(1) < (2), (3), (4) (3) < (2)
Competitor Related Information	1.9130 (1.2028)	2.7500 (.9665)	2.3929 (1.4991)	1.8929 (1.4231)	NS	(2) > (4) (c)
Customer Related Information	1.0000 (1.5076)	.6500 (1.5313)	.7500 (1.9173)	2.3571 (2.2479)	4.7902**	(4) > (1), (2), (3)
Cost/Price Related Information	2.3043 (1.0196)	3.3500 (1.2680)	2.5357) (1.4268)	3.2857 (1.1174)	4.4396**	(2) > (1), (3) (4) > (1), (3)
Technology / Science Related Information	2.8696 (1.7659)	3.9000 (1.6827)	3.0357 (1.8951)	2.0714 (1.4639)	4.5416**	(4) < (2), (3)
Manufacturing Related Information	.6957 (.8221)	1.0000 (.7947)	1.2143 (.5681)	2.0000 (1.4657)	8.1388***	(4) > (1), (2), (3)

(a) Group mean and standard deviation (in parentheses) are based on the absolute number of different information flows between functional departments which were subjectively pointed by the interviewee and were regarded as significant to the project. the minimum number of this indicator is zero when no information was acquired. However, there is no maximum number for this indicator because different information types may have different sets of communication channels. This indicator does not intend to interpret the differences of information redundancy between information types; rather, it is aimed at comparing the differences between different contingent situations.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test Comparisons.
(c) (2) > (4) denotes that the mean of group (2) is significantly larger than the mean of group (4), based on P<.05 level.
(d) * P < .05, ** P < .01, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Information Redundancy and External Contingent Situations

Supplier/component and product related information transmission for NPD under turbulent market conditions reflect a higher level of information redundancy during product development than those in a stable market situation. As mentioned in the last chapter, NPD occurring under turbulent market conditions must maintain fast manufacturing capability and, therefore, needs more redundant transmission of information concerning suppliers, components, and the product itself. NPD in a declining market, however, shows a higher tendency toward redundant customer information transmission than those projects confronting other market situations. This may be due to a stronger sense of the crisis of losing customers in the declining market. NPD in such a situation require richer communication of customer related information so players can keep track of changing customer needs. Clearly, NPD in either a turbulent or declining market will encounter higher uncertainty than in a stable market. Empirical results in the current study echo the findings of Keller (1994) that more communication channels are required for highly uncertain projects.

Information Redundancy and Internal Contingent Situations

Holland et al. (1976) , Shenhar (1993) and Keller (1994) reported that highly uncertain projects, high technology projects, and nonroutine tasks rely on the use of more communication channels to gain richer information transmission during NPD. Empirical findings from the current study suggest that these previous observations only partially explain the phenomena of NPD information transmission. This study's results suggest that narrow classification of NPD into only radical and incremental ones may limit researchers' ability to fully describe firms' information transmission behaviour. The association of radical innovation with redundant communication may be valid only for Hard-to-Produce Radicals. Easy-to-Produce Radicals seem not to reflect high information redundancy during NPD.

For Hard-to-Produce Radicals, there is a tendency for players to use a greater variety of channel types to transmit goal/strategy related information than other NPD. This may be due to the higher capital investment (e.g., prototyping, tooling) in developing this type of highly risky new product. The redundant communication may be useful in reducing project uncertainty. Hard-to-Produce Radicals also show a higher level of redundancy than other new product types when information concerning regulation, law, and industrial standard are considered. One possible explanation is that Hard-to-Produce Radicals tend to be highly complicated projects. They need to comply with regulations and industrial standards more thoroughly. Highly redundant communication during NPD facilitates the understanding and sharing of such information.

For supplier/component and cost/price related information, Hard-to-Produce Radicals and Tried and Tested Incrementals show a higher level of information redundancy during NPD than Easy-to-Produce Radicals and Untried Incrementals. The development teams of Hard-to-Produce Radicals and Tried and Tested Incrementals need to be well informed about the availability of components/materials/systems and the acceptability of development cost so as to maintain the capability of fast and low-cost manufacturing. However, there are also differences between the two. Hard-to-Produce Radicals are more technology-oriented and, therefore, tend to use higher redundant NPD communication for sharing technology/science related information than do the Tried and Tested Incrementals. On the other hand, Tried and Tested Incrementals seem to be more mass-production-oriented and, hence, tend to have a richer use for manufacturing related information than do Hard-to-Produce Radicals.

Other differences between Hard-to-Produce Radicals and Tried and Tested Incrementals concerning the level of information redundancy during NPD are their modes of transmitting competitor and customer related information. On the one hand, radical innovations tend to be those creating future customer needs. Technological competence is highly important in such a situation. Hard-to-Produce Radicals seem to encounter greater pressure from the technological competition of their global rivals and, therefore, require a higher level of information redundancy in communicating competitor related information than do Tried and Tested Incrementals. Customer-led innovations tend to be the incremental ones. Tried and Tested Incrementals tend to follow customer needs in developing their product concepts and hence require a richer communication for customer related information than do Hard-to-Produce Radicals.

Untried Incrementals also show a higher information redundancy in sharing technology/ science related information. This may be due to a lack of necessary technological knowledge for developing an unfamiliar new product. However, both Easy-to-Produce Radicals and Untried Incrementals seem to use less redundant communication for transmitting most NPD information. In particular, Easy-to-Produce Radicals seem to rely highly on small group communication. This may be due to the fact that Easy-to-Produce Radicals are concerned mainly with technology-based information. As a result, they tend to limit their communication to technology only, which is most preferable within group discussion.

§7.4 The Selection of NPD Communication Channels and Contingent Situations

> ***Hypothesis 3.5:*** *For successful NPD, the nature of communication channels employed during product innovation varies significantly with the type of new product project undertaken.*

> ***Hypothesis 3.6:*** *For successful NPD, the nature of communication channels employed during product innovation varies significantly with the dynamics of its incumbent market-place.*

The selection of NPD communication channels is measured in terms of the use of direct or indirect and formal or informal communication channels (Figure 7.1). Direct channels are defined as communication media that transmit information through direct or face-to-face communications during NPD. This may include such communication channels as direct interactions, meetings, seminars, or electronic groupwares. On the other hand, indirect channels are those that transmit information without direct interaction between information senders and receivers, for example, documentation, official document circulation, or Fax messages. One exception, the e-Mail (Electronic Mail) message system is treated as half direct and half indirect channel as it can be used as either on-line or off-line. The measure of direct or indirect channel types therefore is calculated in terms of the percentage of direct channels taking into account all channel types being used during NPD. Transferred to the one to nine scale, one denotes that all NPD information was communicated through direct channels; nine denotes all information was transmitted through indirect channels. For a particular type of information, those cases that did not acquire such information (i.e., the number of channels is zero) were treated as system missing.

Similar to the above classification of channel types, formal channels are communication channels for formalized information transmission during NPD, e.g., meetings, seminars, documentation, and official document circulation. Informal channels, on the other hand, are those channels based on an informal style of communication, such as direct interactions, Fax/telephone message. E-Mail message system is also treated as a half formal and half informal channel as it can be used as either on-line or off-line. The measure of formal or informal channel types is calculated as the percentage of formal channels taking into account all channel types being used during NPD. Transferred to a one to nine scale, one denotes that all NPD information was communicated through formal channels; nine denotes all information was transmitted through informal channels. For a particular type of information, those cases that did not acquire such information (i.e., the number of channels is zero) were also treated as system missing.

Key Findings

Tables 7.6 and 7.7 present the use of channel types under external contingent situations. From the examination of the use of direct or indirect channel types, statistical results show little evidence that the use of channel types for NPD communication is contingent upon market situations. Only two out of ten information types show significant differences (Duncan test, $P < 0.05$) in the use of direct or indirect communication channels. For the use of formal or informal channel types under external contingent situations, four out of ten information types were found significant in ANOVA and/or Duncan test treatments. Hypothesis 3.6 is partially supported.

Tables 7.8 and 7.9 present the use of channel types for different new product situations. Eight out of ten information types show significant differences among different task types in terms of the use of communication channels during NPD giving strong support for Hypothesis 3.5.

Discussions

Channel Types and External Contingent Situations

For market related information, most NPD tend to use formal and somewhat indirect

Table 7.6 External Contingent Situations and the Use of Direct or Indirect Communication Channels

Information Type	Environmental Situations (b) (1) Turbulent Market	(2) Declining Market	(3) Stable Market	F	Duncan Results*
Market Related Information	6.4872 (a) (3.5159) n=39	5.6923 (3.7923) n=26	7.8077 (2.6541) n=26	NS (d)	(3) > (2) (c)
Cost/Price Related Information	2.8571 (3.2578) n=42	2.2857 (2.8913) n=28	1.3793 (1.5678) n=29	NS	(1) > (3)

(a) Group mean and standard deviation are based on the measurement of direct or indirect communication channels used for NPD information transmission. Direct Channel is defined as information transmission through direct, face to face, or finger to finger (e.g., electronic message) communication during NPD. Such channel types may be classified as direct interactions, meetings, seminars, or electronic groupwares. Indirect Channel is defined as information transmission without direct interaction between information sender and receiver, e.g., documentation, official document circulation, or Fax/telephone message. One exception, E-mail is treated as 50% of direct and 50% of indirect channel.
Index of channel type, calculated in terms of the percentage of direct channels being used. While transferring to a 1 to 9 scale, 1 denotes that all information was communicated through direct channels; 9 denotes all information was transmitted through indirect channels. Those cases that did not acquire the particular information during NPD (i.e., the number of channels is 0) were treated as system missing.
(b) (1), (2), and (3) are group identification numbers for Duncan Test Comparisons.
(c) (3) > (2) denotes that the mean of group (3) is significantly larger than the mean of group (2), based on P<.05 level.
(d) * P < .05, NS: Not Significant. All Duncan results are based on P<.05 comparison.

channels (e.g., a marketing survey report) for communicating information. However, NPD in a declining market involves the use of direct and informal communication channels much more than in the case of other market conditions. Moreover, for customer related information, NPD in a declining market also show a higher tendency for informal communication channels to be used. Both direct and informal communication channels tend to be richer and more efficient than other types of communication (e.g., Nagpaul and Pruthi, 1979; Voss, 1989; Stevenson and Gilly, 1991). This is consistent with the results in the last chapter that new product developer in a declining market tend to have a stronger fear of losing existing markets and, therefore, require a much richer and more effective communication concerning markets and customer related information. This also confirms the findings of Holland et al. (1976) that direct, informal, and rich communication channels were critical for projects encountering highly uncertain situations.

For product and technology/science related information, NPD in a turbulent market

Table 7.7 External Contingent Situations and the Use of Formal or Informal Communication Channels

Information Type	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
Market Related Information	1.5641 (a) (1.8333) n=39	2.9615 (3.4232) n=26	1.9231 (2.4153) n=26	NS (d)	(2) > (1) (c)
Customer Related Information	3.5000 (3.4736) n=20	6.5385 (2.4703) n=13	4.0000 (4.1404) n=8	3.4119*	(2) > (1)
Product Related Information	2.1667 (2.3262) n=42	4.7857 (3.5419) n=28	5.2759 (3.9901) n=29	9.6530***	(1) < (2), (3)
Technology / Science Related Information	5.0238 (3.4108) n=42	6.6071 (3.0592) n=28	7.7241 (2.3283) n=29	7.0642**	(1) < (2), (3)

(a) Group mean and standard deviation are based on the measurement *of formal or informal* channels used for NPD information transmission. Formal Channel is defined as the information which was transmitted through a formalized channel during NPD. Such channel types may include meetings, seminars, documentation, or official document circulation. Informal Channel is defined as the information which was transmitted through an informal channel during NPD, e.g., direct interactions and Fax/telephone message. E-mail is treated as 50% of formal and 50% of informal channel.
Index of the channel type thus is calculated by the percentage of formal channels being used. In transfer to a 1 to 9 scale, 1 denotes that all the information was transmitted through formal channels; 9 denotes all the information was transmitted through informal channels. Those cases that did not acquire particular information during NPD (i.e., *the number of channels* is 0) were treated as system missing.
(b) (1), (2), and (3) are group identification numbers for Duncan Test Comparisons.
(c) (2) > (1) denotes that the mean of group (2) is significantly larger than the mean of group (1), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

tends to have a greater tendency than others to reflect formal channels for information transmission. As NPD under such a situation tends to focus on the firm's manufacturing capability rather than the innovativeness of a specific technology (see Chapter 6), it is necessary to formalize functional consensus about the product as well as technology specifications so as to smooth the process of manufacturing. Finally, for cost/price related information, NPD in a stable market situation seem to use more direct channels than others while transferring information during NPD. In a stable market firms tend to concern more about development and manufacturing cost (also see Chapter 6) and, therefore, many direct channels for sharing cost/price related information are required.

Table 7.8 Internal Contingent Situations and the Use of Direct or Indirect Communication Channels

Information Type	Task Differences (b) (1) Easy-to-Produce Radicals	(2) Hard-to-Produce Radicals	(3) Untried Incrementals	(4) Tried & Tested Incrementals	F	Duncan Results*
Goal/Strategy Related Information	1.0000 (a) (.0000) n=23	2.2000 (2.6278) n=20	1.0000 (.0000) n=25	1.1905 (.8729) n=21	4.0153* (d)	(2) > (1), (3), (4)
Regulation, Law, and Industrial Standard	7.2222 (3.1353) n=18	8.9500 (.2236) n=20	8.6667 (1.6330) n=24	8.6087 (1.6717) n=23	3.1296*	(1) < (2), (3), (4)
Supplier, Component Related Information	4.2308 (3.6091) n=13	8.3500 (1.5985) n=20	4.6429 (3.7733) n=28	5.8214 (3.7024) n=28	5.8932**	(2) > (1), (3), (4)
Competitor Related Information	7.4737 (2.7763) n=19	8.5263 (1.2635) n=19	6.0000 (3.5401) n=24	6.1250 (3.6512) n=24	3.2388*	(2) > (3), (4) (c)
Product Related Information	1.1739 (.8341) n=23	3.2000 (3.5482) n=20	3.1429 (2.9779) n=28	2.2857 (2.6785) n=28	2.8965*	(1) < (2), (3)
Technology / Science Related Information	1.4348 (1.1995) n=23	1.1000 (.4472) n=20	2.3214 (2.6674) n=28	4.0000 (3.7118) n=28	6.6952***	(4) > (1), (2), (3)
Manufacturing Related Information	2.4545 (3.2362) n=11	1.0000 (.0000) n=16	3.1538 (3.6188) n=26	4.0000 (3.8682) n=28	2.9299*	(4) > (2)

(a) Group mean and standard deviation are based on the measurement of direct or indirect communication channels used for NPD information transmission. Direct Channel is defined as information transmission through direct, face to face, or finger to finger (e.g., electronic message) communication during NPD. Such channel types may be classified as direct interactions, meetings, seminars, or electronic groupwares. Indirect Channel is defined as information transmission without direct interaction between information sender and receiver, e.g., documentation, official document circulation, or Fax/telephone message. One exception, E-mail is treated as 50% of direct and 50% of indirect channel.
Index of channel type, calculated in terms of the percentage of direct channels being used. While transferring to a 1 to 9 scale, 1 denotes that all information was communicated through direct channels; 9 denotes all information was transmitted through indirect channels. Those cases that did not acquire the particular information during NPD (i.e., the number of channels is 0) were treated as system missing.

(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test Comparisons.

(c) (2) > (3), (4) denotes that the mean of group (2) is significantly larger than the means of group (3) and group (4), based on P<.05 level.

(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Channel Types and Internal Contingent Situations

Overall, more informal and direct channels are found in Easy-to-Produce Radicals than other types of NPD for transferring most types of NPD information (e.g., goal/strategy, market, regulation, law, industrial standard, product, and technology/science related information). This suggests that Easy-to-Produce Radicals may encounter a higher level of uncertainty during development, which requires a higher level of richness and efficiency of information transmission.

By contrast, for most information types, Hard-to-Produce Radicals utilize more indirect and formal communication channels than others for transferring information (e.g., goal/strategy, regulation, law, industrial standard, supplier/component, competitor, and product related

Table 7.9 Internal Contingent Situations and the Use of Formal or Informal Communication Channels

Information Type	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals	(2) Hard-to-Produce Radicals	(3) Untried Incrementals	(4) Tried & Tested Incrementals		
Goal/Strategy Related Information	6.3913 (a) (3.7385) n=23	2.4000 (2.9092) n=20	4.2000 (4.0000) n=25	3.8571 (3.8247) n=21	4.3837** (d)	(1) > (2), (3), (4)
Market Related Information	3.3684 (3.5467) n=19	2.2632 (2.7657) n=19	2.0000 (2.6077) n=26	1.0741 (.3849) n=27	3.2154*	(1) > (4) (c)
Regulation, Law, and Industrial Standard	1.7222 (2.0524) n=18	1.0000 (.0000) n=20	1.0417 (.2041) n=24	1.0870 (.4170) n=23	NS	(1) > (2), (3), (4)
Product Related Information	4.7826 (3.6922) n=23	1.9000 (2.4688) n=20	5.0357 (3.5744) n=28	3.1786 (3.3339) n=28	4.4164**	(2) < (1), (3)
Technology / Science Related Information	6.9130 (2.6270) n=23	6.3000 (2.9397) n=20	7.3571 (2.8459) n=28	4.6071 (3.6346) n=28	4.2644**	(4) < (1), (3)

(a) Group mean and standard deviation are based on the measurement of formal or informal channels used for NPD information transmission. Formal Channel is defined as the information which was transmitted through a formalized channel during NPD. Such channel types may include meetings, seminars, documentation, or official document circulation. Informal Channel is defined as the information which was transmitted through an informal channel during NPD, e.g., direct interactions and Fax/telephone message. E-mail is treated as 50% of formal and 50% of informal channel.
Index of the channel type thus is calculated by the percentage of formal channels being used. In transfer to a 1 to 9 scale, 1 denotes that all the information was transmitted through formal channels; 9 denotes all the information was transmitted through informal channels. Those cases that did not acquire particular information during NPD (i.e., the number of channels is 0) were treated as system missing.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test Comparisons.
(c) (1) > (4) denotes that the mean of group (1) is significantly larger than the mean of group (4), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

information). This may be due to the nature of Hard-to-Produce Radicals that is complex in manufacturing, which requires more indirect and formal channels (e.g,. drawings, technical reports) to transfer knowledge from product development to manufacturing. Only for technology/science and manufacturing related information do Hard-to-Produce Radicals show a strong tendency to use direct communication channels. This may suggest that Hard-to-Produce Radicals have standardized or systemized some of the information transmission processes and therefore can focus their efforts on issues of technology and manufacturing.

Clark and Fujimoto (1990) presented the Honda case and suggested that Japanese style innovation management prefers direct and informal communications during NPD. Shenhar (1993) and Keller (1994) also reported that high technology projects or nonroutine tasks tend to use direct and informal interactions for NPD communication. According to the current study, the above assertions may only reveal part of the truth: (1) these assertions may only be valid for technology/science based communications, (2) for other information types, these assertions may only be valid for Easy-to-Produce Radicals.

Untried Incrementals and Tried and Tested Incrementals seem to use all types of communication channels. Untried Incrementals show a higher tendency than other NPD to use direct channels for transmitting goal/strategy, supplier/component, competitor, and technology/science related information. However, for transmitting regulation, law, industrial standard, and product related information, Untried Incrementals seem to use more indirect channels than others. Untried Incrementals also show a higher tendency to use informal channels for communicating product and technology/science related information. This may indicate that Untried Incrementals require effective interaction for assessing new venture feasibility in terms of technology and necessary components. However, they can learn from competitors about product design as well as regulations and industrial standards for the design without conducting actual technological research.

On the other hand, Tried and Tested Incrementals show a higher tendency than others to communicate regulation, law, industrial standard, technology/science, and manufacturing related information through indirect channels and transfer goal/strategy, supplier/component, and competitor related information through direct channels. They also tend to use more formal channels than others for transferring goal/strategy, market, regulation, law, industrial standard, and technology/science related information. This may be due to the fact that technology/science, regulation/law/industrial standard, market knowledge, and manufacturing competencies of Tried and Tested Incrementals have been formally established through previous development experiences. The capability of responding to the competitive situation, to reduce material/component cost, and to achieve a more effective strategic move is therefore more important.

Similar to the cases of radical innovations, the assertion of Shenhar (1993) that low technology projects should employ formal channels for NPD communication is only partially confirmed. His assertion may only be valid for Tried and Tested Incrementals. For Untried Incrementals, although the employed technology may be simple, unfamiliarity with this project type still causes firms to pursue more effective ways (e.g., informal channels) for communication.

§7.5 Summary of Information Transmission under Contingencies

This chapter examines whether NPD information transmission activities are contingent upon external and internal factors. Three issues are specifically highlighted to observe how successful firms communicate and share information during NPD. These issues include:

- the degree of departmental coupling,
- the extent of information redundancy, and
- the selection of communication channel types.

Overall, the results suggest that internal factors are better predictors than external ones for NPD information transmission behaviour. In addition, the level of departmental coupling is not very relevant to both internal and external contingent situations. However, there is strong evidence suggesting that the extent of information redundancy and the selection of channel types for NPD are contingent upon task types. Table 7.10 summarises the comparison of information transmission activities and how they vary with external and internal contingent factors.

Table 7.10 Summary of NPD Information Transmission Activities under Contingent Situations

Information Transmission Behaviour	Mean	External Contingencies			Internal Contingencies			
		Turbulent Market	Declining Market	Stable Market	Easy-making Radicals	Hard-producing Radicals	Inexperienced Incrementals	Proficient Incrementals
Goal/Strategy Related Information								
Departmental Coupling (scale: 0-7)	1.8182							
Information Redundancy (I)	.9495				moderate	higher	moderate	lower
Information Redundancy (II)	2.0303							
Indirect Channels (scale: 1-9)	1.3146				less	more	less	less
Informal Channels (scale: 1-9)	4.2809				more	less	moderate	less
Market Related Information								
Departmental Coupling (scale: 0-7)	1.1212							
Information Redundancy (I)	1.0303							
Information Redundancy (II)	2.3333							
Indirect Channels (scale: 1-9)	6.6374	moderate	less	more				
Informal Channels (scale: 1-9)	2.0659	less	more	moderate	more	moderate	moderate	less
Regulation, Law, and Industrial Standard								
Departmental Coupling (scale: 0-7)	.8788							
Information Redundancy (I)	.8788							
Information Redundancy (II)	1.1919				lower	higher	lower	lower
Indirect Channels (scale: 1-9)	8.4118				less	more	more	more
Informal Channels (scale: 1-9)	1.1882				more	less	less	less
Supplier/Component Related Information								
Departmental Coupling (scale: 0-7)	1.2020				lower	higher	higher	higher
Information Redundancy (I)	1.0505	higher	lower	lower	lower	higher	higher	higher
Information Redundancy (II)	1.9899	higher	moderate	lower	lower	higher	moderate	higher
Indirect Channels (scale: 1-9)	5.7865				less	higher	less	moderate
Informal Channels (scale: 1-9)	1.8090							
Competitor Related Information								
Departmental Coupling (scale: 0-7)	1.0505							
Information Redundancy (I)	.9899							
Information Redundancy (II)	2.2121				moderate	higher	moderate	lower
Indirect Channels (scale: 1-9)	6.9186				more	more	less	less
Informal Channels (scale: 1-9)	1.6977							
Customer Related Information								
Departmental Coupling (scale: 0-7)	.6465				moderate	lower	lower	higher
Information Redundancy (I)	.5051	moderate	higher	lower	lower	lower	lower	higher
Information Redundancy (II)	1.2424	lower	higher	lower	lower	lower	lower	higher
Indirect Channels (scale: 1-9)	3.3415							
Informal Channels (scale: 1-9)	4.5610	less	more	moderate				
Cost/Price Related Information								
Departmental Coupling (scale: 0-7)	2.2323							
Information Redundancy (I)	1.0505							
Information Redundancy (II)	2.8586				lower	higher	lower	higher
Indirect Channels (scale: 1-9)	2.2626	more	moderate	less				
Informal Channels (scale: 1-9)	1.5758							

Table 7.10 (Continued)

Information Transmission Behaviour	Mean	External Contingencies			Internal Contingencies			
		Turbulent Market	Declining Market	Stable Market	Easy-making Radicals	Hard-producing Radicals	Inexperienced Incrementals	Proficient Incrementals
Product Related Information								
Departmental Coupling (scale: 0-7)	1.5758							
Information Redundancy (I)	1.1717	higher	moderate	lower				
Information Redundancy (II)	3.2929							
Indirect Channels (scale: 1-9)	2.4545				less	more	more	moderate
Informal Channels (scale: 1-9)	3.8182	less	more	more	more	less	more	moderate
Technology/Science Related Information								
Departmental Coupling (scale: 0-7)	1.0000							
Information Redundancy (I)	1.2929							
Information Redundancy (II)	2.8990				moderate	higher	higher	lower
Indirect Channels (scale: 1-9)	2.3434				less	less	moderate	more
Informal Channels (scale: 1-9)	6.2626	less	more	more	more	moderate	more	less
Manufacturing Related Information								
Departmental Coupling (scale: 0-7)	1.1717				lower	lower	moderate	higher
Information Redundancy (I)	.8586				lower	lower	higher	higher
Information Redundancy (II)	1.2727				lower	lower	lower	higher
Indirect Channels (scale: 1-9)	2.9259				less	less	more	more
Informal Channels (scale: 1-9)	2.3827							

Chapter Eight

The Management of NPD Knowledge Creation and Accumulation

8

The preceding chapters have discussed how firms acquire and share NPD related information under a variety of contingency situations. This chapter further examines the knowledge creation and accumulation process subsequent to the above information processing activities. To achieve successful knowledge management for NPD, firms are required to establish mechanisms for facilitating the successful transformation of information to knowledge. Through in-depth interviews, three different types of roles are identified as bridging the two ends, information and knowledge, i.e., information facilitators, information digesters, and knowledge accumulators. The utilisation of these roles is therefore examined in terms of NPD under different contingent situations. Statistical results suggest that external contingent situations have very little effect upon the use of information facilitators, information digesters, and knowledge accumulators, while internal contingent situations do have a strong effect.

8 The Management of NPD Knowledge Creation and Accumulation

§8.1 Introduction

Successful utilisation of NPD information is based on high quality implementation of information sharing, information assimilation, and knowledge accumulation. The main purpose for NPD information processing is to use and retain knowledge resultant from these activities. Knowledge is the fruit of learning. To carry out such a learning process in an organisational context, firms need to provide mechanisms for guiding and promoting knowledge creation and accumulation. Two aspects of learning mechanisms can be observed: (1) the media used in the learning process, and (2) the attitude of the firm to information. Based on in-depth interviews, the current study found that the media used in the learning process include documentation, human-based learning, machine-based learning, and the construction of standard operation procedures. These learning approaches can also be classified as outward sharing or inward concentrating. ***Outward sharing*** denotes a consensus among NPD members that information should be shared around the organisation so as to enrich and enlarge the base for knowledge creation and accumulation. This approach to learning encourages communication and interaction among all functional departments as well as between the firm and its outside world. On the other hand, ***inward concentrating*** highlights the need for a small number of key people to acquire and reserve knowledge. This approach to learning regards information and knowledge as critical properties belonging to the organisation, not to be shared with the public. The small number of key people is regarded as the "brain of the NPD machine", while others are merely the arms and legs.

The following discussions are based on the above conceptualisations about learning approaches for new product development. By using ANOVA and Duncan Multiple Range Test, the use of NPD information facilitators, information digesters, and knowledge accumulators is compared with regard to external and internal contingent situations.

§8.2 Contingent Situations and the Use of Information Facilitators

> ***Hypothesis 4.1:*** *For successful NPD, the managerial arrangements for facilitating information processing vary significantly with the type of new product project undertaken.*
>
> ***Hypothesis 4.2:*** *For successful NPD, the managerial arrangements for facilitating information processing vary significantly with the dynamics of its incumbent marketplace.*

An information Facilitator is defined as any specific managerial arrangement for smoothing the sharing and the circulating of NPD related information. This study identified thirteen distinct types of information facilitators which have been involved in providing opportunities for information sharing. During the in-depth interviews, interviewees were asked to describe any specific managerial arrangements that were used to assist the process of information acquisition and transmission as well as the effectiveness of such a managerial arrangement. As the current study did not provide any pre-defined list or instructions for the interviewees, the resultant list of facilitators is quite diversified. Moreover, such a list may also be greatly influenced by the focal research region, i.e., Taiwan. In other countries the list may be different. However, they fit into the two-dimensional framework as presented in Figure 8.1. Among these information facilitators, On-line Groupwares, Computer Networking, and Global Information Sharing are treated as two-facet in terms of the mode for processing information; they can be used for concentrating as well as sharing information. In the coding process for statistical analyses, for those NPD projects that did not use a particular type of information facilitator, the coding value is zero which denotes that such information facilitator was not actually used. For those that actually utilized a particular type of information facilitator, the coding value one suggests a poor implementation while two and three denote respectively a moderate and an excellent implementation of such an arrangement.

Project Monitor Committee

A Project Monitor Committee is a group of people, representing most of the functional departments in the organisation, who are responsible for directing/monitoring NPD project

Figure 8.1 Information Facilitators in the Context of New Product Development

	human-based	machine-based
sharing	Project Monitor Committee Multi-discipline Stage Review Multi-discipline Happy Club Multi-discipline In-Service Training Information Sharing Seminars Company-wide Participation of Product Design Consumer Participation of Product Design	On-line Groupwares Computer Networking Global Information Sharing
concentration	Keeping Original Team Members Designer as Sale Force Chief Scientist as NPD Supervisor	On-line Groupwares Computer Networking Global Information Sharing

Source: the current study.

direction/progress. In Taiwan, members of the committee are often senior managers of functional departments at director or vice president level. Functional departments represented often include CEO, R&D, Marketing, and Manufacturing.

Multi-discipline Stage Review

Multi-discipline Stage Review is a regular procedure for reviewing project progress as well as defining implementation details. Members participating are often senior engineers from R&D and manufacturing departments and deputy managers from other supportive functions such as marketing, purchasing, tooling, finance, and information service.

Multi-discipline Happy Clubs

These are non-official social associations financially supported by firms, aimed at bringing together members from different functional departments for a fun night or happy weekend. This is especially useful in building consensus between Marketing and R&D during product design.

On-line Groupware

Groupware is a computerised system that incorporates documentation automation, office automation, database, electronic mail, calendar (group scheduling) management, and full-text (or hypertext) searching capability in a network environment. On-line groupware provides opportunity for participants to communicate and share information or knowledge in a free, autonomous, but organized way. All the resultant information or knowledge from such an electronic group discussion can promptly be stored electronically and retrieved later.

Computer Networking

Computer Networking denotes networking facilities (e.g., eMail system, on-line engineering database, etc.) for NPD members but not necessarily groupware systems. Groupware systems involve much more advanced utilisation of computer networking.

Multi-discipline In-Service Training

This is a personnel policy that provides opportunity for employees to cross functional departments to learn different skills as well as to enlarge their view of the business. By such a process, information or knowledge that originally belongs to a particular functional department can be diffused. This is especially useful in reducing the "not invented here" syndrome and promoting mutual consensus among functions.

Keeping Original Team Members

In most circumstances humans learn through practice. This kind of knowledge is often very tacit and personal and therefore it is not satisfactory to preserve it by non-human media or to allow it to be fully taken over by other people. To cope with this situation, some firms try to maintain a policy that keeps original team members to support and continue subsequent development work for a particular new product class. Information and knowledge related to such a new product therefore can be more easily acquired, understood, and accumulated.

Designer as Sales Force

To provide a window for product designers to observe and interact with customers, in some firms, R&D engineers take turns to serve as sales forces for a fixed period per year. This is very useful for the engineers to access first-hand marketing related information and to acquire feedback about their own design from consumers.

Information Sharing Seminars

An Information Sharing Seminar is a means for members from different NPD projects to share their knowledge, experiences, and problems encountered from their just-released-work. In many firms it has been the norm for project leaders to present an overview of their project results to the R&D department (sometimes also including members from other departments such as marketing and manufacturing). It is therefore much easier to circulate and internalize project-related information across the organisation.

Global Information Sharing

Using computer networking technology, many Taiwanese firms have established world-wide networking with their overseas subsidiaries, suppliers, dealers, and the allied companies. Information from all over the world is now promptly available.

Company-wide Participation in Product Design

Some firms encourage employees from the whole organisation to contribute their ideas, suggestions, and comments to new product design. This often incorporates a three-stage process: (1) employees participating in the idea generation process with the R&D members; (2) outcomes from concept development (e.g. clay models) circulating throughout the organisation; and (3) prototypes circulating and being tested by employees before the pilot run.

Consumer Participation in Product Design

Some companies allow consumer participation during product design. Similar to the company-wide participation in product design, consumers are often invited to contribute their ideas, suggestions, and comments to: (1) idea generation, (2) concept development, and (3) prototype validation. These participating customers are often intentionally selected and financially supported with a formal contract.

Chief Scientist as NPD Supervisor

Although the nature of scientific work is often distinct from that of development work, some Taiwanese firms do try to bridge these two ends by using their chief scientist as NPD supervisor. In such a case the chief scientist often leads a small team consisting of technological experts and is responsible for solving any technical problems raised by NPD project teams. He also acts as a teacher for diffusing technology-related knowledge to his fellow R&D members, and is very often authorized to guide the direction of all NPD. In some companies he even has the absolute power to command staff in other functional departments, such as marketing and manufacturing. In effect, while only considering technology-related information, he is at the centre of the organisation's communication network.

Key Findings

According to statistical analyses, external contingent situations show little effect upon the use of information facilitators. Hypothesis 4.2 is rejected. However, internal contingent situations (i.e. task types) do show strong influences upon NPD concerning the use of information facilitators. Hypothesis 4.1 is supported. Tables 8.1 and 8.2 show results on the use of information facilitators under internal contingent situations. Table 8.1 compares the use of information facilitators identified in the study based on different NPD types. Table 8.2 presents the statistical results on the utilisation of information facilitators classified into human-based versus machine-based information acquisition, and outward information sharing versus inward information concentration.

Overall, the most popular tools used by Taiwanese firms for facilitating information processing are global information sharing, a project monitoring committee, and computer networking. The multi-discipline happy club, multi-discipline in-service training, and company-wide participation of product design are relatively rare. However, among different types of NPD, the utilisation of these tools does vary.

Radical innovations seem to have a greater tendency to use a variety of information facilitators to ease information processing. Moreover, Hard-to-Produce Radicals are more likely to use human-based information acquisition and have a greater tendency to share information among members than other types of NPD. In other words, Hard-to-Produce Radicals show a higher tendency to provide an open, more humanized environment for product innovation, while the R&D for Easy-to-Produce Radicals seem to be more closed and computerised.

Discussions

It is not surprising that external contingent factors show little effect upon the use of information facilitators, although, in theory, external variables should be considered to complete a contingency system. Hypothesis 4.2 is based on the assumption that if NPD information

Table 8.1 Internal Contingent Situations and the Utilisation of Information Facilitators

Information Facilitators	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)		
Project Monitor Committee	.7826 (a) (1.3469)	1.8500 (1.4256)	1.3214 (1.4920)	1.8214 (1.4920)	2.8310* (d)	(1) < (2), (4) (c)
Multi-discipline Stage Review	.2174 (.7359)	1.7500 (1.4835)	.3214 (.8630)	.5357 (1.1701)	9.1149***	(2) > (1), (3), (4)
Multi-discipline Happy Club	.0000 (.0000)	.2000 (.6156)	.4286 (1.0690)	.1071 (.5669)	NS	(3) > (1)
On-line Groupwares	.7826 (1.1264)	.2000 (.6156)	.1071 (.5669)	.2500 (.7515)	3.5479*	(1) > (2), (3), (4)
Computer Networking	1.7826 (1.4758)	1.2000 (1.3992)	.9286 (1.3859)	1.0357 (1.4268)	NS	
Multi-discipline On-the-job Training	.0000 (.0000)	.3000 (.9234)	.0000 (.0000)	.1071 (.5669)	NS	
Keep Original Team Members	1.5652 (1.4717)	.6500 (1.0894)	1.1071 (1.2864)	.8929 (1.2573)	NS	(1) > (2)
Designer as Sales Force	.3913 (1.0331)	.3000 (.9234)	.1071 (.5669)	.2143 (.7868)	NS	
Information Sharing Seminars	1.3913 (1.4058)	1.9500 (1.4681)	.7500 (1.3229)	.3214 (.9449)	7.3532***	(2) > (3), (4) (1) > (4)
Global Information Sharing	1.4348 (1.5323)	2.2500 (1.3328)	1.0714 (1.4639)	1.1786 (1.4920)	2.9298*	(2) > (3), (4)
Company-wide Participation of Product Design	.3913 (1.0331)	.0000 (.0000)	.2857 (.8545)	.4286 (1.0690)	NS	
Consumer Participation of Product Design	.7391 (1.2142)	.1500 (.6708)	.3929 (.9940)	.3214 (.9449)	NS	
Chief Scientist as NPD Supervisor	1.1739 (1.4970)	1.3500 (1.5313)	.8571 (1.3801)	.2143 (.7868)	3.6612*	(4) < (1), (2)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of how firms use information facilitators. Information Facilitators are defined as managerial arrangements that can be used to facilitate information processing. During the in-depth interviews, interviewees were requested to describe any specific managerial arrangements designed for improving information processing. Scales: 0 = not in use; 1 = poor quality of implementation; 2 = moderate quality; 3 = excellent quality.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (1) < (2), (4) denotes that the mean of group (1) is significantly smaller than the means of group (2) and group (4), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 8.2 Internal Contingent Situations and the Nature of NPD Information Facilitators

Information Type	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)		
Human-based Acquisition	.6652 (a) (.2994)	.8500 (.3017)	.5571 (.3863)	.4964 (.2782)	5.2929** (d)	(2) > (3), (4) (c)
Machine-based Acquisition	1.3333 (1.1192)	1.2167 (.8040)	.7024 (.9222)	.8214 (.9958)	NS	(1) > (3)
Outward Information Sharing	.7522 (.4220)	.9850 (.4069)	.5607 (.5216)	.6107 (.4332)	3.9851*	(2) > (3), (4)
Inward Information Concentration	1.1884 (.8694)	.9917 (.6081)	.6964 (.6432)	.6310 (.5355)	3.7486*	(1) > (3), (4)

(a) Group mean and standard deviation (in parentheses) are based on the classification of thirteen types of information facilitators identified from in-depth interviews (see Figure 8.1). Interviewees were asked to describe any specific managerial arrangement designed for facilitating information acquisition or transmission. The scales: 0=never use such facilitator; 1=use it but the quality is poor; 2=use it and have a moderate quality; 3=use it and the quality is excellent.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (2) < (3), (4) denots that the mean of group (2) is significantly larger than the means of group (3) and group (4), based on P<.05 level.
(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

processing is contingent upon external factors, the management of information assimilation and accumulation should follow the same pattern (see Chapter Three). However, the previous two chapters have shown that external situations do not significantly influence all information processing activities. As a result, the sample firms also tend not to put too much effort into adapting the use of information facilitators for external project situations.

Three reasons may explain the lesser significance of external factors in predicting NPD information processing. First, Lilien and Yoon (1989) highlighted that internal (organisational) determinants are controllable variables, while market/environmental factors are uncontrollable and dynamic. It would be much easier for firms to focus on the tuning of NPD management to internal factors, rather than to the unpredictable external environment. Secondly, Lieberman and Montgomery (1988) stated that some of the "incumbent inertia" may make it difficult for new product pioneers to adapt to environmental change. Successful new product developers may have already established excellent, but maybe more formalized, systems for product innovation. In turn, such systems may reduce the motivation for firms to adjust to their external environment. This view is supported by Leonard-Barton (1992a) that those core capabilities which served the company well in the past may become rigidities -- which reduce the responsiveness of the firm to its environment. Thirdly, Cooper (1979) also found that environmental variables do not play a critical role in deciding new product performance. Calantone and di Benedetto (1990) further suggested that a compound effect exists within and between internal and external variables to determine NPD success or failure. As environmental variables are uncontrollable, firms might as well focus on the more important internal contingent factors so as to manage NPD effectively.

Easy-to-Produce Radicals show a higher tendency than others to use on-line groupware and information sharing seminars, to keep original team members, and to use a chief scientist as a NPD supervisor for improving knowledge acquisition. They also tend to use less than others a project monitor committee, multi-discipline stage review, and multi-discipline happy club. This may be due to the fact that the major concern in conducting this type of NPD is scientific technology, which is known to a few key people and which is difficult to share with others who have less technological background. Moreover, as this type of NPD is easy to produce and often regards itself as creating customers' future needs, there is little necessity for R&D to communicate with people from other disciplines. It requires little investment in prototyping or manufacturing and, therefore, can easily be imitated if anyone has the know-how. Firms need to regard these core technologies as well-protected trade secrets, which should only be circulated among a few key people. As a result, machine-based facilitators and an inward concentration mode for information processing are more popular for this type of NPD.

Hard-to-Produce Radicals seem to make better use than other types of NPD of tools such as the project monitoring committee, multi-discipline stage review, information sharing seminars, global information sharing, and chief scientist as NPD supervisor. On the other hand, they seem to be less dependent on on-line groupwares and the keeping of original team members. This may be due to the fact that this type of NPD relies heavily on people's experience/knowledge from different disciplines. Hard-to-Produce Radicals tend to have a longer development cycle and are more difficult to produce. They require more investment in prototyping and manufacturing and so bear greater financial risk in case of a market failure. For them, product technology is important, but not the only ingredient for successful product innovation. The consensus of technology used, availability of key components, capability of manufacturing, and acceptability in the marketplace needs to be achieved through information sharing and multi-discipline coupling. As a result, human-based information sharing is the best approach for managing this type of NPD.

Untried Incrementals are more likely to use the multi-discipline happy club than are other types of NPD. This may be due to the need of this NPD type to reduce project uncertainty because it is totally new to the firm. An informal setting for multi-discipline information sharing provides the richest way to explore unfamiliar (but not so difficult) product development. On the other hand, Untried Incrementals seem to make less use of multi-discipline stage review, on-line groupware, information sharing seminars, and global information sharing than others.

Tried and Tested Incrementals seem to be more likely to use project monitor committee than others and make less use of multi-discipline stage review, on-line groupwares, information sharing seminars, global information sharing, and chief scientist as NPD supervisor. In the case of Tried and Tested Incrementals the R&D function seems to have less authority in the organisation than do other NPD types. Very often the marketing or manufacturing function has even greater power in deciding NPD direction. The project monitor committee may be a good for functional consensus and therefore smoothing this type of product innovation.

Finally, statistical results also suggest that the use of information sharing and human-based innovation management, strongly advocated by the Japanese Studies (see Section 2.5.4), may not be universally appropriate. According to this study, the use of such approaches may only be valid for Hard-to-Produce Radicals. In effect, the sampling frame in most Japanese Studies (e.g., Clark, et al. 1987; Clark and Fujimoto, 1990, 1991; Nonaka, 1990, 1991) is Hard-to-Produce Radicals. On the one hand, their observations are highly consistent with the characteristics of Hard-to-Produce Radicals revealed in the current study. On the other, their findings may be biased with regard to sample selection and may not be still valid when applied to other new product types.

§8.3 Contingent Situations and the Use of Information Digesters

Hypothesis 4.3: *For successful NPD, the managerial arrangements for facilitating information assimilation vary significantly with the type of new product project undertaken.*

Hypothesis 4.4: *For successful NPD, the managerial arrangements for facilitating information assimilation vary significantly with the dynamics of its incumbent marketplace.*

Information digester is defined as any specific managerial arrangement that was used by the sample firms to improve the processing of NPD information into useful knowledge. Similar to the identification of information facilitators discussed in the last section, NPD information digesters were also defined through in-depth interviews. The interviewees were requested to describe any specific managerial arrangements designed for improving the assimilation of NPD information into useful knowledge. They were also asked to rate the quality of such implementations, i.e., poor, moderate, or excellent. Five types of information digester were identified by the current study, i.e., learning via a few key people, learning via all team members, learning via documentation, learning via electronic machine, and learning via organisational procedure.

Learning via a Few Key People

In this case a few key people (e.g., decision makers, chief scientist) act as the centre of communication networks. They exclusively hold all critical information in the organisation. Learning occurs when these few key people assimilate information into personal tacit knowledge.

Learning via All Team Members

In this case information is shared by all team members. Every individual has the same right to access information. Learning occurs when information is assimilated by any individual and the resultant knowledge is pased to all team members (i.e., internalisation).

Learning via Documentation

Strictly speaking, learning via documentation cannot be regarded as knowledge creation. However it does help to assimilate information into knowledge. In this case all NPD-related information, such as events, technical problems/solutions, and empirical findings, are well recorded and organised in documentation form. Through this recording process, tacit knowledge and experiences therefore can be more easily translated into explicit knowledge.

Table 8.3 Internal Contingent Situations and the Utilisation of Information Digesters

Information Digesters	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Learned by a Few Key People	3.0000 (a) (.0000)	3.0000 (.0000)	2.7500 (.7993)	3.0000 (.0000)	NS (d)	(3) < (1), (4) (c)
Learned by a Group of People	.9130 (1.4114)	1.8000 (1.5079)	.5357 (1.1701)	.5357 (1.1701)	4.6413**	(2) > (1), (3), (4)
Learned by Documentation	2.8261 (.4910)	2.7000 (.7327)	2.6429 (.5587)	2.7143 (.5345)	NS	
Learned by Electronic Machine	.4783 (.9472)	.0500 (.2236)	.1429 (.5909)	.1429 (.5909)	NS	(1) > (2)
Learned by Organisational Procedure	1.1304 (1.1403)	1.5000 (1.0000)	.5714 (1.0338)	1.0000 (1.1547)	2.9632*	(2) > (3)

(a) Group mean and standard deviation (in parentheses) are based on the measurement of how firms use information digesters. Information Digesters are defined as managerial arrangements that can be used to improve the digesting of information into knowledge. During the in-depth interviews, interviewees were requested to describe any specific managerial arrangements designed for improving information digesting. Scales: 0 = not in use; 1 = poor quality of implementation; 2 = moderate quality; 3 = excellent quality.

(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.

(c) (3) < (1), (4) denots that the mean of group (3) is significantly smaller than the means of group (1) and group (4), based on P<.05 level.

(d) * P < .05, ** P < .01, *** P < .001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Learning via Electronic Machine

Similar to the above learning via documentation, learning via electronic machine records daily events, technical problems/solutions, and empirical findings into retrievable database. By using computer networking and groupwares, this recorded information can easily be shared and maintained by team members simultaneously. Even further, knowledge bases and expert systems can be established for guiding NPD decision making.

Learning via Organisational Procedure

This is the most thorough type of learning that adapts the organisation's value system. In this case, information is not only assimilated by key individuals and team members into knowledge, but also translated into organisational norms, values, and procedures for guiding daily activities. Organisational re-engineering is possibly necessary, when there is a significant conflict between the old values and the new.

Key Findings

Statistical results suggest that external contingent situations have no effect upon the use of information digesters within the NPD context. Hypothesis 4.4 is rejected. Considering internal contingent situations, the use of four out of five information digesters varies among task types. Hypothesis 4.3 is accepted. Table 8.3 shows internal contingent situations and the use of information digesters.

Discussions

Not surprisingly, external factors again show little effect upon the pattern of NPD information assimilation. As explained in the last section, three causes may weaken the influences from external environment upon NPD information processing, i.e., (1) external variables are uncontrollable and, therefore, tend to be ignored by firms; (2) successful new product developers tend to establish a certain level of "incumbent inertia", which blocks their responsiveness to the environment; and (3) it is suggested empirically that external variables are less significant in deciding NPD performance. Thus, it would not be so harmful if a firm put more organisational resources into coping with internal factors.

However, the rejection of Hypothesis 4.4 also suggests that most Taiwanese firms are still capable only of single-loop learning rather than double-loop learning. Their learning mechanisms reflect only their internal needs without considering external dynamics. As Taiwanese firms are weak in double-loop learning, they are extremely vulnerable to external environmental change. The high shake-out rate of firms in Taiwan (see Section 4.5.2) corroborates the above observations.

Overall, "learning via a few key people" and "learning via documentation" are the most popular routes Taiwanese firms use to convert information into useful knowledge. This suggests that Taiwanese firms are very weak in applying organisational learning theory into practical management. Most firms still rely heavily on documentation and individual elite; the loyalty of key people decides the future of the firm. Furthermore, radical innovations seem to use more information digesters with a better quality of information assimilation than do the incremental ones. This may be due to the nature of technology employed by these new products. Radical innovations tend to be high-tech ones; they require better mechanisms to assimilate information into knowledge.

Easy-to-Produce Radicals seem to use more "learning via a few key people" and "learning via electronic machine" than do other types of NPD. On the other hand, Hard-to-Produce Radicals seem to use more "learning via all team members" and "learning via organisational procedures" and use less "learning via electronic machine" than others. Consistent with their utilisation of information facilitators, Easy-to-Produce Radicals tend to use machine-based learning and concentrate information to a few key people, while Hard-to-Produce Radicals prefer human-based information sharing. It is clear that information assimilation is based on competence in information processing. In addition, the approaches used by firms for information processing also influence their mode of information assimilation. Similar to the findings presented in the last section, the assertion in Japanese studies that NPD should adopt a human-based information sharing scheme to foster information assimilation may also be biased because of their limited sampling frame -- only for Hard-to-Produce Radicals (e.g., Clark, et al. 1987; Clark and Fujimoto, 1990, 1991; Nonaka, 1990, 1991). For different NPD types, the use of different approaches for information assimilation may be necessary to generate successful product innovation.

§8.4 Contingent Situations and the Use of Knowledge Accumulators

Hypothesis 4.5: *For successful NPD, the managerial arrangements for facilitating knowledge accumulation vary significantly with the type of new product project undertaken.*

Hypothesis 4.6: *For successful NPD, the managerial arrangements for facilitating knowledge accumulation vary significantly with the dynamics of its incumbent marketplace.*

Knowledge Accumulator is defined as any specific managerial arrangement that was used by the sample firms to accumulate knowledge or experiences learned from NPD projects. By using the same procedure for identifying information facilitators and digesters, knowledge accumulators are identified by the current study as documentation, scattered computer files, organised computer databanks, and "keeping key people".

Key Findings

Overall, documentation and "keeping key people" have been the major means for Taiwanese firms to store NPD knowledge from daily operations. However, when incorporating the effects of external and internal contingent situations, statistical results show little difference in the use of knowledge accumulators between different NPD types. For each type of contingent situation (i.e., external and internal), only one out of four knowledge accumulators is found to vary with different NPD types. Both hypotheses 4.5 and 4.6 are partially supported.

Discussions

Although, in theory, this study hypothesizes that both internal and external contingent factors should show effects upon NPD knowledge management, firms may encounter difficulties in adapting their learning systems to fit specific project situations. This is due to the fact that any organisational learning system is a result of long-term adaptation of organisational values and skills from historical experiences. The limitation imposed by the cross-sectional research approach used by the current study makes it difficult to observe the evolutionary process of a learning system.

For external contingent situations, NPD under stable market situations seem to use more documentation than others in accumulating NPD knowledge (Duncan Test: $P < 0.05$). This may be due to the fact that firms in a stable environment tend to have better opportunity to establish complete documentation systems for storing and retrieving information (and knowledge), although documentation in reality is not a very suitable means of managing knowledge. The use of "keeping key people" may be a better means for reserving knowledge. However, as all NPD recognize the importance of key people in managing organisational memory, it would be surprising to find differences between NPD in terms of using this means.

For internal contingent situations, Easy-to-Produce Radicals seem to better utilize the organized computer databank in reserving NPD knowledge (ANOVA: $P < 0.0001$ and Duncan Test: $P < 0.05$). This is consistent with previous findings that Easy-to-Produce Radicals tend to use more computerised means for managing information.

§8.5 Summary of Management of NPD Knowledge Creation and Accumulation

This chapter investigates the management of NPD knowledge creation/accumulation and how it varies with different situations. Three stages of NPD knowledge management are considered, i.e., facilitation of information processing, assimilation of information, and accumulation of knowledge. Statistical results suggest that external contingent situations have little effect upon the use of information facilitators, information digesters, and knowledge accumulators. However, it is also true that the use of these managerial tools is dependent upon internal contingent situations (i.e., NPD types).

Overall, radical innovations seem to use more means for managing knowledge creation and accumulation, and they are of better quality. Hard-to-Produce Radicals also show a higher tendency to use more human-based learning and welcome information-sharing across the organisation. On the other hand, Easy-to-Produce Radicals seem to utilise more machine-based (i.e., computer systems) approaches than others for managing knowledge. The attitude to information sharing of Easy-to-Produce Radicals also tends to be more inward, and closed, while also concentrating on only a few key people.

This chapter focuses on the use of knowledge creation and accumulation tools for transferring personal implicit information into organisational knowledge. However, issues concerning single-loop or double-loop organisational learning have yet to be fully discussed. As these issues are often related to the design of organisational structures/procedures rather than the use of "managerial tools", a further investigation of NPD organisational learning may be necessary. This will be discussed in the next chapter.

Chapter Nine

Corporate-level Versus Project-level Structural Design

9

As demonstrated in the last few chapters the management of NPD information processing and knowledge accumulation is contingent upon a variety of project situations/conditions. Nevertheless, these discussions are based merely on the observations of project-level activities. It is interesting to know whether the managerial arrangements for product innovation are better deployed at project-level or at corporate-level. By focusing on issues of organisational structural design, this chapter examines how successful firms allocate their resources at project- and corporate-level. Statistical results suggest that firms rarely adapt themselves promptly to fit their external environment. They also tend not to remodel their NPD structure at corporate-level when encountering any situational change. However, results from fieldwork show strong evidence that successful firms do contingently adapt themselves for product innovation at project-level.

9 Corporate-level Versus Project-level Structural Design

§9.1 Introduction

Many scholars researching into NPD structural design have concentrated their effort on corporate-level organisational deployment, asserting that a well-designed NPD structure at this level can generate successful innovations. However, there has not yet been a consensus among these studies with regard to the best structure. Some researchers favour the small, flat, and organic structure so as to accelerate organisations' innovativeness (Quinn, 1985; Shrivastava and Souder, 1987; Peters, 1990; Rothwell, 1992; Saleh and Wang, 1993), while others stress the value of the large, formal, and centralised research laboratory that can increase resource efficiency and productivity (Grady and Fincham, 1990). There have been relatively few project-level structure studies. Larson and Gobeli (1988) and Gray et al. (1990) empirically confirmed that both project matrix and project team structures performed well for NPD. However, they did not report whether corporate-level structural design has contributed to the performance of their cases.

To what extent should a firm shape itself to suit a particular NPD? It is interesting to know whether managerial arrangements for product innovation are better deployed at project-level or at corporate-level. As corporate organisational re-structuring is highly time-consuming and costly, it is unlikely that firms will organise or re-organise resources on a company-wide scale to accommodate the requirements of every project. Moreover, it is possible that several projects are carried out simultaneously, which makes the adaptation of corporate NPD structure for every individual project impossible. It would be much more reasonable and efficient for firms to employ a flexible system that adjusts their team management models at project level. Therefore, the current study asserts that firms will tailor their NPD management systems to cope with contingency situations at project level rather than at corporate level.

Based on in-depth interviews, seven types of corporate NPD management model and eight types of team management model were identified. These models were differentiated as design approaches that focused on facilitating either single- or double-loop learning. Patterns of team composition as well as the use of NPD procedure models are also discussed.

§9.2 Corporate NPD Management Models and Contingent Situations

Hypothesis 5.1: *For successful NPD, firms tend not to tailor their NPD management models at the corporate-level for every specific type of product innovation.*

Hypothesis 5.2: *For successful NPD, firms tend not to tailor their NPD management models at the corporate-level in coping with the market dynamics of a specific project.*

Corporate NPD Management Models deal with the relationships between R&D and other functional departments at corporate-level. In the current study, seven types of corporate NPD management model were identified through in-depth interviews. Although some of these models may be exclusive to Taiwanese firms, to some extent they have parallels in western structural designs, for example, the differentiation of "line", "line-and-staff", "functional", and "organic" structure (Jermakowicz, 1978: 109), or the "functional" and "project" organisation (Allen, 1986). These organisational studies do provide general rules for guiding organisational structure design; however they concentrate on the investigation of the models' leadership style and staff authority, rather than on revealing relationships between different disciplines in an organisation. Corporate NPD Management Models identified in the current study highlight the control mechanisms and interfaces between R&D and other functional departments (Figure 9.1). From this point of view, the models presented here in essence are different from those in other studies. The following shows the possible parallels of these models with other studies, although they may not be identical.

(1) **Task Force Model**: Venture Team (Jermakowicz, 1978; Bonnet, 1986), Project Organization (Allen, 1986), Product Cell (Garnsey and Wright, 1990), Task Force (Carlsson, 1991; Loehr, 1991).

(2) **Project Committee Model**: functional organisation (Allen, 1986).

(3) **Programme Dominant Model**: functional organisation (Allen, 1986).

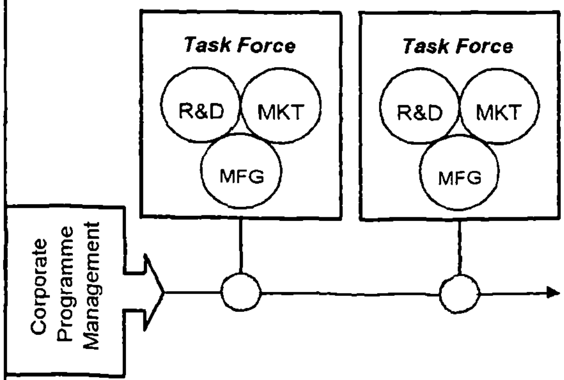
(4) **Team Dominant Model**: Project Task Force (Bonnet, 1986).

(5) **CEO Dominant Model**: Traditional Structure (Webber et al., 1985: 379).

(6) **Matrix Model**: Matrix Structure (Jermakowicz, 1978; Might and Fischer, 1985; Garnsey and Wright, 1990; Carlsson, 1991).

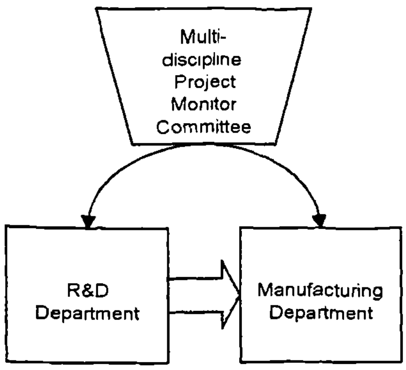
(7) **Functional Model**: Functional Structure (Webber et al., 1985: 415-7; Allen, 1986), Special R&D Unit (Garnsey and Wright, 1990).

Figure 9.1 Corporate NPD Management Models



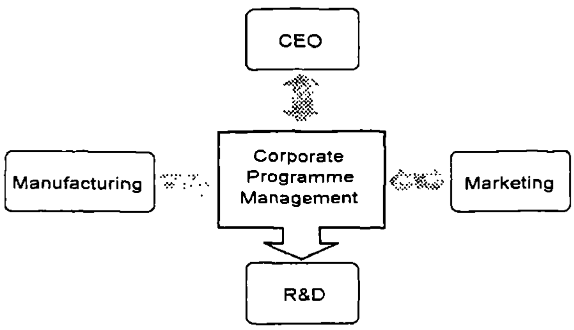
Type 1:
Task Force Model

R&D, Manufacturing (MFG), and Marketing (MKT) functions are combined and sliced into task forces by product categories so as to better support and maintain each product line in a long-term perspective. Each task force consists of all three functions and is fully responsible for the commercial performance of the particular product line. A supportive department at corporate level (i.e., Corporate Programme Management) is formed to allocate corporate resources (e.g., time, man power, equipment, and money) to these task forces. Learning Centre: team members; Learning Type: double-loop (with multi-discipline integration and boundary expansion).



Type 2:
Project Committee Model

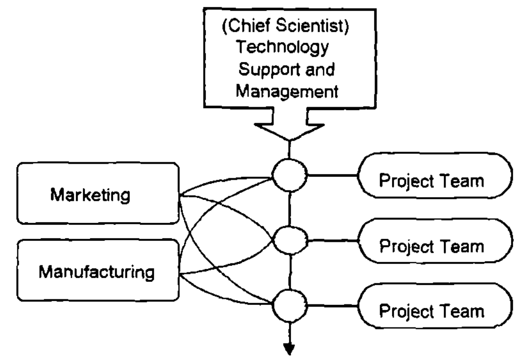
A project monitor committee consists of CEO and senior members from functional departments such as Marketing, R&D, Manufacturing, and acts as the command post for all NPD-related decision making. Learning Centre: decision makers (members of the committee); Learning Type: double-loop (with multi-discipline integration and boundary expansion).



Type 3:
Programme Dominant Model

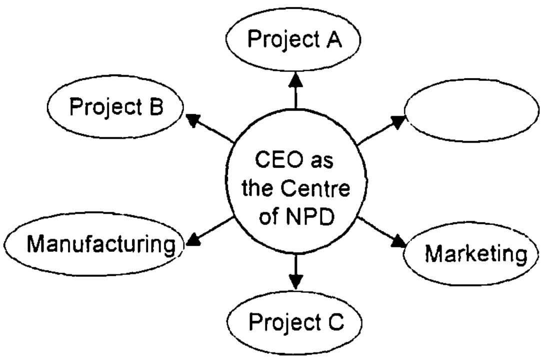
Corporate programme management is the centre of organisational operations. On one hand, it defines the direction and schedule for all NPD programmes; on the other hand, it also acts as an interface between R&D and other functional departments for filtering NPD-related communication. Learning Centre: team members; Learning Type: single-loop (without direct functional integration and boundary expansion).

Figure 9.1 (Continued)



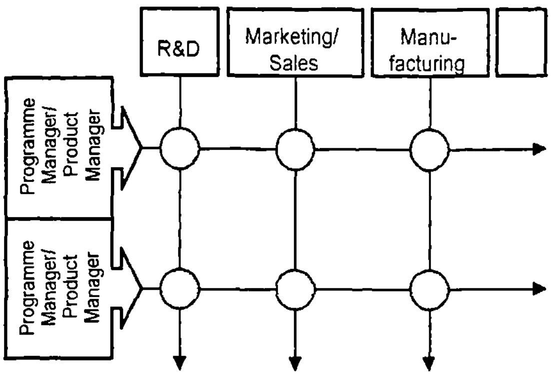
Type 4:
Team Dominant Model

R&D function is sliced into several small groups based on the product categories and is supervised by the chief scientist/engineer who is responsible for all NPD decision making and technical troubleshooting. Project leaders are the key persons in corporate-level operations who are responsible for functional NPD-related communications. Learning Centre: key individual (the chief scientist); Learning Type: double-loop (with functional integration and boundary expansion).



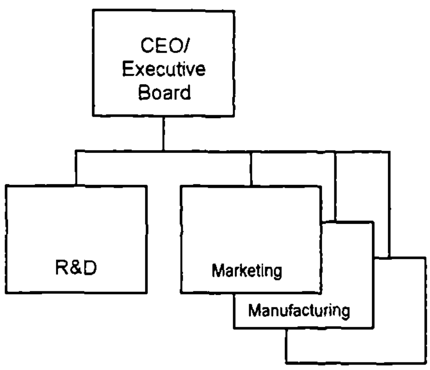
Type 5:
CEO Dominant Model

CEO acts as the centre of NPD who alone makes all NPD decisions and decides the direction of all projects. Such CEOs are often entrepreneurial founders of corporations with strong scientific/technological background. Learning Centre: decision maker (CEO); Learning Type: single-loop (without external integration and boundary expansion).



Type 6:
Matrix Model

The whole company is reformed into a NPD-oriented organisation in which all functional departments are coordinated through matrix management by product categories. Functional coordinators are assigned from functional departments for each product category. These functional coordinators therefore work together as a team and are led by a product/programme manager. Learning Centre: key individuals (functional coordinators); Learning Type: double-loop (with integration and boundary expansion among functional departments).



Type 7:
Functional Model

This is the most traditional type of functional organisation. R&D is treated as one of the functional departments in the organisation. Communications among functional departments are through formal channels in the organisational pyramid. Learning Centre: team members; Learning Type: single-loop (without external integration and boundary expansion).

Source: the current study

Although these organisational designs can be roughly classified into functional or project organisation (e.g., Allen, 1986), the essence of these models shows great differences in two ways. First, these structural designs provide different levels of opportunities for functional integration and boundary expansion and, therefore, highlight different approaches to organisational learning. As suggested by Organisational Learning studies (see Section 2.5.5), a structural design that encourages external integration and boundary spanning would increase the proficiency of double-loop organisational learning, while promoting within-unit single-discipline information sharing could facilitate single-loop organisational learning. Explicit differentiation of double- or single-loop learning is important for strategic planning. Double-loop learning highlights the need for self-reflection and self-correction of activities, which suggests a focus on long-term rather than short-term effectiveness of operations. Single-loop learning stresses the importance of short-term rather than long-term efficiency in a specific domain.

Secondly, these structural designs embed different types of learning centres that are used to accumulate NPD-related knowledge at organisational level. For some models, team members are at the centre of organisational learning, normally granted higher autonomy as well as responsibility for NPD projects. They often present a higher level and a wider scale of participation in the projects than those of other model types. On the other hand, the learning centre for some models is centred on a few people, such as decision makers or key individuals. In such cases, team members often play less significant roles in the NPD process. The people who actually implement product innovation are those key individuals; the team members are merely technical assistants.

Key Findings

As explained in the last section, the current study asserts that these corporate NPD management models are NOT influenced by external or internal contingent situations. Firms are hypothesized as having less motivation to adapt their organisational structure corporate-wide to cope with the dynamics of single projects. ANOVA and Duncan test results support the above assertions. There is little difference in terms of the use of corporate NPD management models among NPD types which encountered different contingent situations. Hypotheses 5.1 and 5.2 are accepted. Tables 9.1 and 9.2 give the statistical analysis.

The use of single- or double-loop learning approaches and their corresponding learning centres in corporate NPD management models are also examined. As expected, Chi-Square results show that the use of learning approaches and learning centres depends neither on external nor internal NPD situations. Hypotheses 5.1 and 5.2 are further confirmed.

Discussions

Overall, firms show a higher tendency to use the Functional Model, Matrix Model, or Team Dominant Model for implementing their corporate NPD strategies. This reflects the fact that most previous NPD structure studies centred on investigating these models (e.g., Might and Fischer, 1985; Allen, 1986; Carlsson, 1991). Moreover, external contingent situations seem to have a minor effect upon firms in terms of the use of corporate NPD management models. Firms in a stable market situation show a higher tendency to use Programme Dominant Model than

Table 9.1 External Contingent Situations and the Use of Corporate NPD Management Models

Corporate NPD Management Models	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
Task Force Model	.0952 (a) (.2971)	.0357 (.1890)	.0000 (.0000)	NS (d)	
Project Committee Model	.1190 (.3278)	.1071 (.3150)	.0690 (.2579)	NS	
Programme Dominant Model	.0476 (.2155)	.0000 (.0000)	.1379 (.3509)	NS	(3) > (2) (c)
Team Dominant Model	.2619 (.4450)	.1429 (.3563)	.2069 (.4123)	NS	
CEO Dominant Model	.0238 (.1543)	.1071 (.3150)	.0690 (.2579)	NS	
Matrix Model	.2143 (.4153)	.1429 (.3563)	.3448 (.4837)	NS	
Functional Model	.2381 (.4311)	.4643 (.5079)	.1724 (.3844)	3.4858*	(2) > (1), (3)

(a) Group mean and standard deviation (in parentheses) are based on the probability of a particular management model been used. Scale: 1 = the particular management model is currently used. 0 = no.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (3) > (2) denotes that the mean of group (3) is significantly larger than the mean of group (2), based on P<.05 level.
(d) * P<.05, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 9.2 Internal Contingent Situations and the Use of Corporate NPD Management Models

Corporate NPD Management Models	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Task Force Model	.0435 (a) (.2085)	.1000 (.3078)	.0357 (.1890)	.0357 (.1890)	NS (c)	
Project Committee Model	.0435 (.2085)	.1500 (.3663)	.0357 (.1890)	.1786 (.3900)	NS	
Programme Dominant Model	.1304 (.3444)	.0000 (.0000)	.0357 (.1890)	.0714 (.2623)	NS	
Team Dominant Model	.2174 (.4217)	.3000 (.4702)	.2500 (.4410)	.1071 (.3150)	NS	
CEO Dominant Model	.1304 (.3444)	.0000 (.0000)	.1071 (.3150)	.0000 (.0000)	NS	
Matrix Model	.3043 (.4705)	.2500 (.4443)	.1786 (.3900)	.2143 (.4179)	NS	
Functional Model	.1304 (.3444)	.2000 (.4104)	.3571 (.4880)	.3929 (.4973)	NS	

(a) Group mean and standard deviation (in parentheses) are based on the probability of a particular management model been used. Scale: 1 = the particular management model is currently used. 0 = no.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) * P<.05, NS: Not Significant. All Duncan results are based on P<.05 comparison.

those in other circumstances. They are also less likely to use the Functional Model which is the dominant form used by most firms in the declining market category. Both Programme Dominant Model and Functional Model use functional structure in organisational design. The main difference between the two lies in the priority given to R&D activities in corporate operations.

Firms in a stable environment have better opportunity to develop NPD-related technology. They tend to spend more money on NPD than others. They are more responsive to change in market and technology than those operating in a declining market (Chapter Five). They also tend to spend more time during NPD to acquire technology/science related information (Chapter Six). Clearly, R&D tend to be the major activity for firms in stable circumstances. This may explain why firms in a stable market tend to use the Programme Dominant Model for managing corporate NPD; this model especially highlights the role of R&D in corporate operations.

On the other hand, R&D tends to play a minor part in firms operating in a declining market (Chapters Five and Six). These firms also tend to use formal channels for transmitting most information types, such as market, customer, product, and technology/science related information (Chapter Seven). Clearly; the use of Functional Model reflects the less significant role of information processing for firms in a declining market. In this case, R&D is merely one of the functional departments in the organisation, without the need to provide special means for facilitating NPD information processing. Like other functional departments, R&D is well controlled, under the supervision of the organisation's hierarchy.

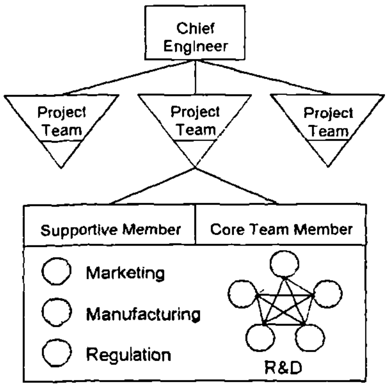
§9.3 Project Team Management Models and Contingent Situations

> ***Hypothesis 5.3:*** *For successful NPD, firms tend to tailor their NPD management models at the project-level for every specific type of product innovation.*
>
> ***Hypothesis 5.4:*** *For successful NPD, firms tend to tailor their NPD management models at the project-level in coping with the market dynamics of a specific project.*

Project Team Management Models define structural designs for managing NPD teams. Figure 9.2 portrays eight types of project team management model identified from in-depth interviews. Some of these models have been discussed by earlier western researchers; however, some of them may be exclusive to Taiwanese firms. Similar to the discussion in the last section, these models may overlap with other NPD structures identified by previous studies. However, they may not be identical. The following shows possible parallels between the Taiwanese and "western" models.

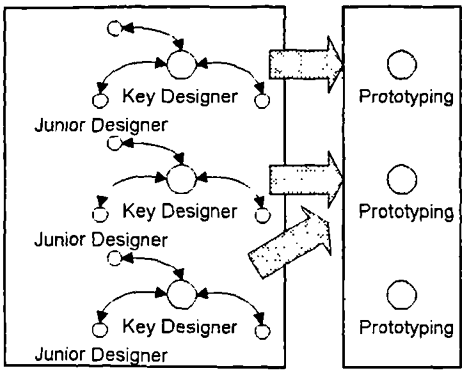
(1) Multi-discipline Model: Project Team (Gray et al., 1990).
(2) Specialisation Model: Functional Projects (Gray et al., 1990).
(3) Super-charged Designer Model
(4) Technology Supported Model
(5) Network Model: Individual/Team Initiative System (Davis and Wilkof, 1988).
(6) Twin Star Model
(7) Matrix Model: Balanced Matrix (Gray et al., 1990).
(8) Virtual Team Model: Virtual Company (Porter, 1993).

Figure 9.2 Project Team Management Models



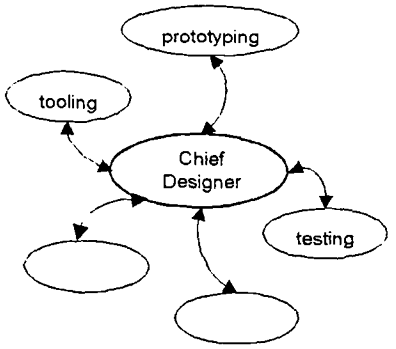
Type 1:
Multi-discipline Model

This model highlights the need for a multi-discipline composition of team members. Along with the researchers and engineers, people from other disciplines such as marketing or manufacturing are also formally incorporated as team members. Learning Centre: team members; Learning Type: double-loop (with multi-discipline integration and boundary expansion).



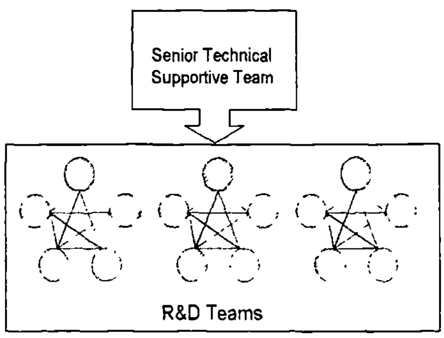
Type 2:
Specialisation Model

Eventually there is no "project" team at all in such a setting. The whole R&D function is divided into groups with specialised sub-functions in terms of the corresponding NPD stages. Similar to the assembly lines for mass-producing products, several NPD projects may be developed and transferred across these sub-functions simultaneously. There is little functional and multi-discipline integration here. Learning Centre: R&D members; Learning Type: single-loop (without external integration and boundary expansion).



Type 3:
Super-charged Designer Model

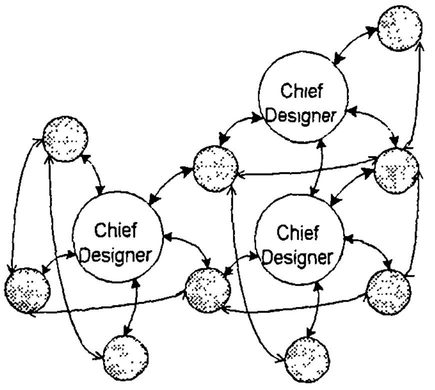
This is a one-man show model. The chief designer is the only key person in the project who gives birth to the product concept, produces prototypes, and takes charge of tooling design and testing. Other team members are merely technical assistants who play minor roles in the NPD process. Learning Centre: key individual (the chief designer); Learning Type: double-loop (with functional integration and boundary expansion).



Type 4:
Technology Supported Model

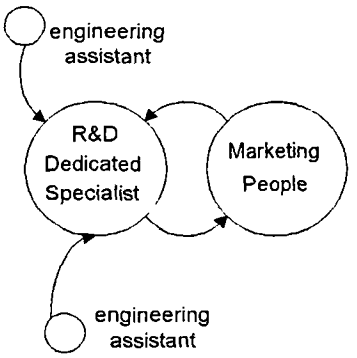
NPD teams are supported by a specialised group of technological experts who are the product concept providers and technology supervisors. Although members in each team are responsible for actual NPD implementation, they often lack enough technological knowledge and training to handle the necessary key technologies in the projects. They do operational routine work and play a minor role in NPD. Functional and multi-discipline integration is also rarely found here. Learning Centre: key individual (the technical supportive team); Learning Type: single-loop (without external integration and boundary expansion).

Figure 9.2 (continued)



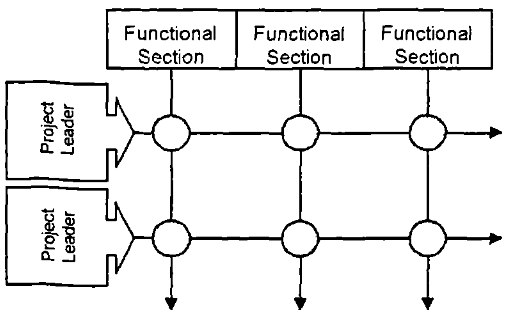
Type 5:
Network Model

R&D function is sliced into small groups based on core technologies. In each group, a senior engineer or scientist is assigned as chief designer responsible for maintaining and enhancing such a core technology. Overlapping of members among groups is highly encouraged which allows a high level of multi-discipline coupling among core technologies. Learning Centre: all R&D members; Learning Type: double-loop (with multi-discipline integration and boundary expansion).



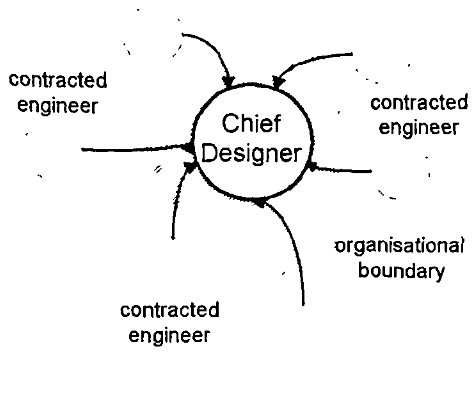
Type 6:
Twin Star Model

Unlike Network Model encourages the sharing of knowledge across different technological disciplines, Twin Star Model promote the integration between the technicians and the non-technicians. R&D and Marketing are separated functions. However, they work together closely in certain NPD activities such as concept development and consumer research. For any particular project, dedicated members from each function are assigned and meet each other on a regular basis but work in their own departments. Learning Centre: team members; Learning Type: double-loop (with functional integration and boundary expansion).



Type 7:
Matrix Model

R&D department is divided into several functional sections based on the specialisation of project tasks (such as industrial design, prototyping, tooling, pilot run, etc.). Task coordinators are assigned from each functional section and are supervised by a project leader. Learning Centre: key individual (the task coordinators from each functional section); Learning Type: double-loop (with functional integration and boundary expansion).



Type 8:
Virtual Team Model

There is only one formal member in the team, i.e., the chief designer. Other members for a particular project are sourced from outside the organisation via task-based contracts. In such a setting normally computer networks among the contracting parties are provided by the chief designer so as to control the project implementation. There is no multi-discipline integration between team members. Learning Centre: key individual (the chief designer); Learning Type: single-loop (without external integration and boundary expansion).

Source: the current study

Similar to the discussion in the last section, these models are distinguished according to their corresponding learning approaches and learning centres. ANOVA and Duncan Tests are employed to examine if these models are used for specific contingent situations. In addition, Chi-Square Independence Tests are implemented to investigate the use of single- or double-loop learning approaches as well as learning centres in contingent situations.

Key Findings

Results from statistical tests suggest that firms tend to adapt their project team structures to different task types (i.e., internal contingent situations). However, external contingent situations have only a minor effect upon the use of these team models. Hypothesis 5.3 is supported while hypothesis 5.4 is partially confirmed.

Discussions

Table 9.3 presents the use of project team management models under external contingency situations. Overall, the Super-charged Designer Model and Matrix Model tend to be the favourite team structures deployed by Taiwanese firms. However, only two out of eight models show significant differences among different market situations. It seems that NPD in a stable market tends not to select Multi-discipline Model for project team management, while those in a turbulent market tend to use this model more frequently. This may be due to the need for much richer and quicker information for NPD under turbulent market conditions than for NPD under stable market conditions. A multi-discipline team structure can bring great benefits in terms of speed of information acquisition as well as extent of multi-discipline communication. On the other hand, NPD in a stable or declining market seems to employ the Technology Supported Model for project team management while no NPD efforts under turbulent market conditions select such a model. One explanation is that the main consideration of NPD in a turbulent market tends to be the maintaining of fast manufacturing capability rather than the novelty of product technology. Therefore, a structural design for facilitating radical technologies during NPD is not so necessary in such cases. This is highly consistent with previous findings presented in the last two chapters.

Table 9.3 External Contingent Situations and the Use of Project Team Management Models

Team Management Models	Environmental Situations (b) (1) Turbulent Market (n=42)	(2) Declining Market (n=28)	(3) Stable Market (n=29)	F	Duncan Results*
Multi-discipline Model	.1429 (a) (.3542)	.0357 (.1890)	.0000 (.0000)	3.1274* (d)	(1) > (3) (c)
Specialisation Model	.1667 (.3772)	.1071 (.3150)	.0690 (.2579)	NS	
Super-charged Designer Model	.2143 (.4153)	.2143 (.4179)	.2414 (.4355)	NS	
Technology Supported Model	0000 (.0000)	.1786 (.3900)	.1379 (.3509)	3.9796*	(1) < (2), (3)
Network Model	.0952 (.2971)	.2143 (.4179)	.2759 (.4549)	NS	
Twin Star Model	.0714 (.2607)	.0714 (.2623)	.1034 (.3099)	NS	
Matrix Model	.3095 (.4679)	.1429 (.3563)	.1379 (.3509)	NS	
Virtual Team Model	.0000 (.0000)	.0357 (.1890)	.0345 (.1857)	NS	

(a) Group mean and standard deviation (in parentheses) are based on the probability of a particular management model been used. Scale: 1 = the particular management model is currently used. 0 = no.
(b) (1), (2), and (3) are group identification numbers for Duncan Test comparisons.
(c) (1) > (3) denotes that the mean of group (1) is significantly larger than the mean of group (3), based on P<.05 level.
(d) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Table 9.4 shows how deployment of project team management models vary according to internal contingency situations. Of the eight models used, seven were found to differ significantly among NPD types. It is clear that some models are exclusive to specific task types. For example, Virtual Team Model is used only by Easy-to-Produce Radicals. Twin Star Model is used only by Inexperienced and Tried and Tested Incrementals. Easy-to-Produce Radicals do not use Specialisation Model. Also, Hard-to-Produce Radicals do not use Technology Supported Model or Network Model.

Overall, Easy-to-Produce Radicals seem to use Technology Supported Model, Network Model, and Matrix Model for NPD implementation. This may be due to the high technological focus of this NPD type, in which within-team communication is greatly promoted so as to

Table 9.4 Internal Contingent Situations and the Use of Project Team Management Models

Team Management Models	Task Differences (b) (1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)	F	Duncan Results*
Multi-discipline Model	.0435 (a) (.2085)	.2000 (.4104)	.0357 (.1890)	.0357 (.1890)	NS (d)	(2) > (1), (3), (4) (c)
Specialisation Model	.0000 (.0000)	.0500 (.2236)	.0714 (.2623)	.3214 (.4756)	5.7945**	(4) > (1), (2), (3)
Super-charged Designer Model	.1304 (.3444)	.2000 (.4104)	.2500 (.4410)	.2857 (.4600)	NS	
Technology Supported Model	.2609 (.4490)	.0000 (.0000)	.0714 (.2623)	.0357 (.1890)	4.0394**	(1) > (2), (3), (4)
Network Model	.2609 (.4490)	.0000 (.0000)	.3214 (.4756)	.1071 (.3150)	3.6091*	(3) > (2), (4) (1) > (2)
Twin Star Model	.0000 (.0000)	.0000 (.0000)	.1786 (.3900)	.1071 (.3150)	NS	(3) > (1), (2)
Matrix Model	.2174 (.4217)	.5500 (.5104)	.0714 (.2623)	.1071 (.3150)	7.4369***	(2) > (1), (3), (4)
Virtual Team Model	.0870 (.2881)	.0000 (.0000)	.0000 (.0000)	.0000 (.0000)	NS	(1) > (3), (4)

(a) Group mean and standard deviation (in parentheses) are based on the probability of a particular management model been used Scale: 1 = the particular management model is currently used. 0 = no.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (2) > (1), (3), (4) denotes that the mean of group (2) is significantly larger than the means of group (1), (3), and (4), based on P<.05 level.
(d) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

facilitate the application of scientific technology into product design. On the other hand, Hard-to-Produce Radicals tend to use Matrix Model, Multi-discipline Model, and Super-charged Designer Model for product innovation. This reflects observations discussed in the last two chapters -- that this type of NPD needs to integrate knowledge from different disciplines (e.g., technology, manufacturing, marketing). The use of the above team management models can help to smooth multi-discipline information sharing. Super-charged Designer Model and Network Model are most frequently used by Untried Incrementals. It is clear that the development of an unfamiliar product type requires both strong technical leadership as well as multi-discipline information sharing. Finally, Specialisation Model and Super-charged Designer Model are widely used in Tried and Tested Incremental cases. This may be due to the fact that this type of NPD needs to pursue cost-leadership and development efficiency. As the technology employed for product design is familiar to the firm, the "assembly line" concept imported from mass-production can be used for accelerating product development cycle.

The learning approaches and learning centres of these team management models are also examined in terms of the proposed internal and external contingent situations. However, only internal contingent situations show significant effects upon the use of learning approaches and learning centres of these team management models. Tables 9.5 and 9.6 list the results of the Chi-Square Independence Test. The Average Expected Frequencies for both tests are 12.3750 and 8.2583 respectively, suggesting that the result in Table 9.5 is highly adequate while the interpretation of the results in Table 9.6 should be treated with caution (Roscoe, 1975: 262).

Interestingly, Hard-to-Produce Radicals and Untried Incrementals seem to have a higher tendency to use team management models that promote double-loop learning than do Easy-to-Produce Radicals and Tried and Tested Incrementals. This suggests that the development of Hard-to-Produce Radicals and Untried Incrementals is strongly associated with a higher level of external integration and boundary spanning activities. This confirms the findings presented in the last two chapters that Hard-to-Produce Radicals need to integrate knowledge from a variety of disciplines rather than only R&D, while Untried Incrementals are those NPD that are unfamiliar to the firms. Both situations encourage external integration and boundary spanning activities.

In considering the use of learning centres, all types of NPD seem to rely heavily on key individuals for accumulating NPD knowledge. However, Hard-to-Produce Radicals and Tried and Tested Incrementals seem have a higher tendency to use team members as the centre of

Table 9.5 Single- or Double-loop Learning of NPD Team Models and Internal Contingent Situations

Learning Approaches	Task Differences				Total
	(1) Easy-to-Produce Radicals	(2) Hard-to-Produce Radicals	(3) Untried Incrementals	(4) Tried & Tested Incrementals	
Single-loop Learning	9 (37.50%)	1 (4.17%)	4 (16.67%)	10 (41.67%)	24
Double-loop Learning	14 (18.67%)	19 (25.33%)	24 (32.00%)	18 (24.00%)	75
Total	23 (23.23%)	20 (20.20%)	28 (28.28%)	28 (28.28%)	99

Pearson Chi-Square=10.32598; Degree of Freedom=3; P<0.05
Average Expected Frequency = 12.3750; Cell with Expected Frequency < 5: 1 of 8 (12.5%)

Table 9.6 Learning Centres of NPD Team Models and Internal Contingent Situations

Learning Centres	Task Differences				Total
	(1) Easy-to-Produce Radicals	(2) Hard-to-Produce Radicals	(3) Untried Incrementals	(4) Tried & Tested Incrementals	
Key Individuals	15 (24.59%)	15 (24.59%)	16 (26.23%)	15 (24.59%)	61
Decision Makers	8 (40.00%)	0 (0.00%)	9 (45.00%)	3 (15.00%)	20
Team Members	0 (0.00%)	5 (27.78%)	3 (16.67%)	10 (55.56%)	18
Total	23 (23.23%)	20 (20.20%)	28 (28.28%)	28 (28.28%)	99

Pearson Chi-Square=20.98521; Degree of Freedom=6; P<0.005
Average Expected Frequency = 8.2583; Cell with Expected Frequency < 5: 4 of 12 (33.3%)

learning, while Easy-to-Produce Radicals and Untried Incrementals tend to rely on corporate decision makers. This may be due to the fact that Hard-to-Produce Radicals and Tried and Tested Incrementals have a greater necessity to promote multi-discipline information sharing. As a result, most team members, not just a few key people, learn throughout the NPD process. On the other hand, Easy-to-Produce Radicals and Untried Incrementals are either the creating of customers' future needs or development of the unfamiliar; both require strong entrepreneurship. As a result, the centre of these NPD tends to be the few key people rather than NPD members as a whole.

§9.4 NPD Process Models and Contingent Situations

Hypothesis 5.5: For successful NPD, the use of NPD process models for fostering product innovation varies significantly according to the type of new product project undertaken.

Hypothesis 5.6: For successful NPD, the use of NPD process models for fostering product innovation varies significantly according to the dynamics of its incumbent marketplace.

The investigation of NPD process models is based on the theoretical work of Shrivastava and Souder (1987) and Souder (1987) who believe that all NPD can be broadly classified into three distinct types of process models (labelled as Core Transfer Models), i.e., Stage-Dominant Models, Process-Dominant Models, and Task-Dominant Models. According to his definition, Stage-Dominant Model refers to the NPD transfer process that is based on a linear sequence with complete transfer of commitments at transfer points. Such a model was also named the Stage-Gate System in which check-points are provided during the development process to ensure the quality of NPD tasks transferred from phase to phase (e.g., Cooper, 1983, 1990; Cooper and Kleinschmidt, 1991). At each check-point, the project can either be rejected or continued. Tasks are not expected to return to any prior phase of NPD. Process-Dominant Model is described as an NPD transfer process based on parallel processing and with very few formal check-points for task transfer. From phase to phase, the current and subsequent parties work together, until both are satisfied that knowledge has been completely handed over to the incoming party. In Task-Dominant Model there is no check-point for task transfer. All tasks are assigned to dedicated teams and are implemented in an organic and dynamic way where each team is systematically related and interdependent. Tasks may also overlap. The development process need not be sequential. All team members enjoy the greatest freedom and autonomy to decide when and how a task should be carried out so as to complete the project.

Key Findings

The current study examines contingent management of the NPD process based on the above models. ANOVA and Duncan Tests suggest that firms tend to adapt their utilisation of NPD process models to the internal contingent situations rather than the external ones. Hypothesis 5.5 is accepted while hypothesis 5.6 is rejected. Table 9.7 presents the adaption of NPD process models to internal contingent situations.

Discussions

Overall, Process-Dominant Model used by 60% to 70% of NPD is the most popular approach reflected by Taiwanese firms. Untried Incrementals, however, show a higher tendency to use Stage-Dominant Model than others. As the nature of Untried Incrementals is a combination of both unfamiliarity and low novelty, on the one hand firms need to take a more conservative approach to diminish project uncertainty, on the other, the low-tech project can still be easily managed by less flexible methods. Stage-Dominant Model satisfies both considerations.

Table 9.7 The Use of NPD Process Models and Internal Contingent Situations

NPD Process Models	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)		
Stage-Dominant Model	.1304 (a) (.3444)	.3500 (.4894)	.4286 (.5040)	.2857 (.4600)	NS (d)	(3) > (1) (c)
Process-Dominant Model	.6087 (.4990)	.6500 (.4894)	.4286 (.5040)	.6786 (.4756)	NS	
Task-Dominant Model	.2609 (.4490)	.0000 (.0000)	.1429 (.3563)	.0357 (.1890)	3.4084*	(1) > (2), (4)

(a) Group mean and standard deviation (in parentheses) are based on the particular process model that was used by the project. Where: 1=yes, 0 = no.
(b) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(c) (3) > (1) denotes that the mean of group (3) is significantly larger than the mean of group (1), based on P<.05 level.
(d) * P<.05, NS: Not Significant. All Duncan results are based on P<.05 comparison.

Easy-to-Produce Radicals seem to use Task-Dominant Model more than others. This may be due to the high-tech, fast-moving nature of this NPD type that requires a more flexible and dynamic process for product development. In addition, as this NPD type is easy to produce, it requires less investment in tooling and manufacturing, i.e., it has lower financial risk in case of project failure. Thus, it need not use conservative approaches (e.g., Stage-Dominant Model) for managing NPD. Results in the study do not fully support the assertion by Souder (1987: 235) that Stage-Dominant Model is best for incremental NPD under stable market conditions, while Task-Dominant Model performs well for radical innovations in a highly uncertain environment. Empirical results suggest that the classification of product innovation into only radical or incremental may over-simplify the nature of NPD. Task-Dominant Model is better utilised by Easy-to-Produce Radicals but not Hard-to-Produce Radicals; Stage-Dominant Model is more frequently found in Untried Incrementals but not Tried and Tested Incrementals.

§9.5 Team Composition and Contingent Situations

***Hypothesis 5.7:** For successful NPD, the project team composition varies significantly according to the type of new product project undertaken.*

***Hypothesis 5.8:** For successful NPD, the project team composition varies significantly according to the dynamics of its incumbent marketplace.*

The last part of this investigation focuses on team composition and how this varies with contingent situations. Six variables are examined, i.e.,

(1) team size;

(2) the proportion of manufacturing people in the team;

(3) the proportion of marketing people in the team;

(4) the proportion of R&D people in the team;

(5) whether there was a shift of team leadership during NPD; and

(6) whether there was a redeployment of team members during NPD.

Key Findings

ANOVA and Duncan Test results suggest that internal contingent situations strongly affect patterns of team composition during NPD, while external ones do not. Hypothesis 5.7 is accepted and hypothesis 5.8 is rejected. Table 9.8 shows patterns of NPD team composition under internal contingent situations.

Discussions

As discussed in Chapter 8, external factors tend not to affect the mode for NPD knowledge creation and accumulation. Such an observation seems to apply to the management of team

Table 9.8 Patterns of NPD Team Composition and Internal Contingent Situations

Team Composition	Task Differences (b)				F	Duncan Results*
	(1) Easy-to-Produce Radicals (n=23)	(2) Hard-to-Produce Radicals (n=20)	(3) Untried Incrementals (n=28)	(4) Tried & Tested Incrementals (n=28)		
Team Size (the number of team members)	6.3913 (a) (2.1896)	12.2000 (11.1242)	6.8214 (2.9446)	7.5000 (7.2903)	3.5169* (d)	(2) > (1), (3), (4)
Manufacturing People in the Team (%)	.0207 (.0573)	.0687 (.1210)	.0839 (.1188)	.1121 (.1718)	NS	(4) > (1) (c)
Marketing People in the Team (%)	.1013 (.1552)	.0536 (.1134)	.2268 (.1543)	.1535 (.1041)	7.4012***	(3) > (1), (2), (4) (4) > (2)
R&D People in the Team (%)	.8780 (.1623)	.8778 (.1518)	.6893 (.1856)	.7344 (.2243)	6.6929***	(1) > (3), (4) (2) > (3), (4)
Whether a shift in Leadership (yes/no)	.1304 (.3444)	.0500 (.2236)	.1429 (.3563)	.3214 (.4756)	NS	(4) > (2)
Whether a change in Team Composition (yes/no)	.4348 (.7278)	.3500 (.5871)	.6429 (.8262)	.9286 (.7664)	2.9721*	(4) > (1), (2)

(a) (1), (2), (3), and (4) are group identification numbers for Duncan Test comparisons.
(b) (4) > (1) denotes that the mean of group (4) is significantly larger than the mean of group (1), based on P<.05 level.
(c) * P<.05, ** P<.01, *** P<.001, NS: Not Significant. All Duncan results are based on P<.05 comparison.

composition during NPD. Firms tend to adapt their policy for NPD team composition and leadership according to task types rather than the environmental dynamics. Sections 8.2 and 8.3 provide three possible causes to explain why external environment shows less significant effect upon NPD information/knowledge management. They are: (1) external variables are uncontrollable and, therefore, tend to be ignored by firms; (2) successful new product developers tend to establish a certain level of "incumbent inertia", which blocks their responsiveness to the environment; and (3) it is suggested empirically that external variables are less significant in deciding NPD performance. Thus, it would not be so harmful if a firm put more organisational resources into coping with internal factors.

Easy-to-Produce Radicals seem to be developed by small teams (mean = 6.4) which contain mainly R&D people (88%) but very few manufacturing (2%) and marketing people (10%). The core team is often well maintained with minor leadership shift (13%) and team redeployment (43%). Hard-to-Produce Radicals have a similar team composition pattern to that of Easy-to-Produce Radicals (i.e., 88% of R&D people, 7% of manufacturing people, and only 5% of marketing people) with very little possibility of leadership shift (5%) and team redeployment (35%). However, the average team size for Hard-to-Produce Radicals is the largest (mean = 12.2). It is clear that the technologies employed in radical innovations are sophisticated, making it difficult to share with other people and, therefore, preventing the original team members from being replaced by other inexperienced engineers. The highly stable leadership and team construction in the cases of radical innovation confirm the observation of Clark and Fujimoto (1990, 1991) that Japanese high-tech firms such as Honda tend to maintain a stable team structure with "heavy-weight project manager" so as to assure product integrity during development.

On the contrary, incremental innovations present quite a different pattern of team composition from that of the radical ones. The team size for developing incremental innovations tends to be smaller than that of Hard-to-Produce Radicals. They also have a higher involvement of manufacturing (8% for Untried Incrementals and 11% for Tried and Tested Incrementals) and marketing people (23% for Untried Incrementals and 15% for Tried and Tested Incrementals) in the project teams. This confirms previous findings that incremental innovations need to maintain their cost-leadership as well as capability of efficient manufacturing. Moreover, as it is necessary for these innovations to better understand customers' current needs, integration of marketing people into the team can help technical people to incorporate such requirements into product design. Meanwhile, the maintenance of core teams seems to be not so important in incremental cases. For Tried and Tested Incrementals, more than 32% encountered a leadership shift and 93% had team redeployment during NPD. This reflects the fact that incremental innovations use simple or familiar technologies in product design. In this case, previous experience with current product innovation is less critical; there is no barrier to limit the replacement of team members during NPD.

§9.6 Summary of NPD Organisational Structure Deployment

This chapter demonstrates how successful firms adapt their corporate as well as project level structures to cope with NPD contingent situations. Statistical findings suggest that firms tend to focus their efforts on project-level structure redesign rather than corporate-level deployment. In the meantime, external contingent factors seem to have less effect upon NPD organisational structure deployment, while internal factors strongly determine the use of team management models, NPD process models, and patterns of team composition.

In general, Easy-to-Produce Radicals seem to highlight the need for structural flexibility in technology exploitation. They tend to use very technology focused team models such as the Technology Supported Model, Network Model and Virtual Team model to make best use of technology. These teams are often small, highly motivated, and focus only on technology-related knowledge sharing (which tends to promote single-loop learning). Meanwhile, the more extensive use of a Task-Dominant process model, the domination of research/scientific people in the team, and the maintenance of original core team members during NPD support the above assertion that flexibility of technology sharing and utilisation are the main concerns of this type of NPD.

Hard-to-Produce Radicals show greater need for multi-functional co-operation during

NPD. They tend more to use a Matrix Model and Multi-discipline Model of organisation than other NPD types. As the nature of such models often encourages inter-functional integration and boundary expansion, NPD teams for developing Hard-to-Produce Radicals seem far more likely to use double-loop learning for knowledge accumulation than others. They tend to use Process-Dominant Model. Team size in these cases is averagely larger than others. However, team composition for Hard-to-Produce Radicals seems to be quite similar to that of Easy-to-Produce Radicals. They often employ research/scientific people as the majority in the team and try to maintain all the original core team members during NPD.

On the contrary, Tried and Tested Incrementals show a different pattern of organisational structure deployment for product innovation. The major considerations for these NPD tend to be speed of development cycle time and feasibility of mass-production rather than full exploitation of product technologies. To achieve these, Specialisation Model for team management is widely implemented. In addition, the most frequently used process model tends to be Process-Dominant Model that provides better functional integration for task transfer from phase to phase. They also tend to involve more manufacturing as well as marketing people in the team for developing this type of new product. A change of leadership and team redeployment during development are common. As the technologies employed in these products are not so radical, there are relatively fewer problems of task transfer from phase to phase. Specialisation Model that flexibly and dynamically redeploys people in different development phases for different task disciplines helps to speed up development cycle time.

Untried Incrementals present a cross between the methods of Tried and Tested Incrementals and Easy-to-Produce Radicals. They are often the boundary extenders of a firm. As a result, they require richer information processing about the availability and feasibility of "on the shelf" technology, rather than formal scientific research. It is not necessary for them to develop NPD structure aimed at technological invention; the key point is how the structure can provide better opportunity for them to utilise existing but unfamiliar technology. On one hand, the use of the Network Model at project-level fosters multi-discipline sharing of information, which helps to identify suitable technologies for NPD. On the other hand, the use of Stage-Dominant Model suggests a relatively conservative approach for managing these unfamiliar technologies during development. Moreover, as the key issue in development is not the invention or utilisation of highly radical technologies, firms can put more effort into understanding the feasibility of technology, marketing, and manufacturing, and the integrity of product design. Twin Star Model that integrates multi-discipline people in a project helps to achieve this purpose. Patterns of team composition for Untried Incrementals also support the above observations. Compared to other NPD types, Untried Incrementals tend to have a higher proportion of marketing people participating with R&D people during NPD.

This chapter presents the final part of the quantitative analyses of NPD management. As stated in the previous chapters, internal contingent factors do strongly affect the pattern of project-level information processing, knowledge accumulation, and NPD structural design. The next chapter will further summarize these findings, based on qualitative case studies.

Chapter Ten

Final Remarks: Qualitative Observation of Project Success and Failure

10

Previous chapters have demonstrated how successful Taiwanese firms excel through contingent management of product innovation. Quantitative results suggest that internal contingent variables (i.e., task types) strongly affect the mode by which firms manage NPD. An integrated view of product innovation management is presented. On the one hand, this thesis provides a complete discussion about the essence of NPD, which includes the management of information acquisition, information transmission, knowledge accumulation, and structural deployments for NPD organisational learning. On the other, this thesis highlights the need for a contingent approach in managing NPD information. Although the results based on quantitative analysis have given a clear picture of effective NPD implementation, it has yet to provide any realistic description of how firms manage product innovation. "A good story is better than a thousand words." This chapter further provides several case studies in an attempt to render a fuller picture of NPD in the real-world.

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10 Final Remarks: Qualitative Observation of Project Success and Failure

§10.1 Introduction

There are two purposes in finally investigating case studies in this thesis. The first is to provide more direct and in-depth observations of the samples used, in an attempt to assist the statistical analysis to present an account of real-world NPD. The second is to confirm and summarise successful ingredients highlighted by the quantitative analyses. These cases are directly selected from in-depth interviews, and to some extent, represent all current research samples. The criterion for selecting these cases is subjective, based on a sense that these cases provide interesting stories about management excellence or failure. However, they are all real-world experiences, in which they are either a success or failure, and they give great intuitional insights into the understanding of NPD practices.

As shown in previous chapters, internal contingent factors have stronger effects upon strategic choices of NPD information and knowledge management than do external factors. Therefore discussion of case studies is based on the differentiation of internal factors, i.e., the task types. Except for Tried and Tested Incrementals which are wholly successful cases, for each task type, two successful and one failed cases are chosen for investigation. In total, this chapter provides eleven case studies which account for about 10% of the total samples. Table 10.1 shows a summary of these cases.

Sections 10.2 to 10.5 present these case studies in this sequence: Easy-to-Produce Radicals, Hard-to-Produce Radicals, Untried Incrementals, and Tried and Tested Incrementals. In each section, quantitative results from previous chapters are summarised to describe possible patterns of information/knowledge management for the specific NPD type. Qualitative case studies follow to confirm findings from quantitative analyses. Conclusions/lessons that can be learnt from these NPD stories are also discussed at the end of each section. A summary of the discussions

Table 10.1 Summary Descriptions of the Case Studies

Project	Company	Project Description	Success/Failure
The Easy-to-Produce Radicals			
DE-650	D-LINK Corporation	The world's first PCMCIA LAN card designed for notebook computers.	success
BEHAVIOR Tran	Behavior Design Corporation	The world's first commercially operated electronic translation machine that can translate English literature into Chinese.	success
Music FaxModem	ZyXEL Communications	The world's first faxmodem that can send, receive, and reproduce electronic messages that include text, image, voice, and music.	failure
The Hard-to-Produce Radicals			
SlimNote586	Twinhead International	The World's first Pentium-based notebook computer that supports the full 64-bit architecture.	success
ScanMaker III	Microtek International	The world's first PC-based 36-bit colour flatbed scanner that can handle up to 68 billion colours.	success
ProKennex 708	Kunnun International	The world's first large-frame tennis racket without a frame support.	failure
The Untried Incrementals			
Papaya Milk	President Enterprises	The first vacuum-packed papaya milk.	success
N-Notes	USI Far East Corporation	Self-stick removable notes.	success
HPB-I	Dah Hsin Industrial Corporation	An office wire/comb binder.	failure
The Tried and Tested Incrementals			
SLTV	Chun Yun Corporation	A series of televisions with normal resolution and definition but equipped with large screens (i.e., from 28" to 37" in diagonal dimensions).	success
SDI Cartridge Stapler	SDI Corporation	A stapler that uses a cassette-loading mechanism so as to fit with a wide range of staple specifications.	success

in this chapter is provided in Section 10.6.

§10.2 Easy-to-Produce Radicals

10.2.1 What Can Be Learnt from the Quantitative Results?

Easy-to-Produce Radicals, as defined in Chapter Five, are NPD that show the following characteristics:

(1) very high profile new products,

(2) high novelty in the marketplace,

(3) high uncertainty at the beginning of product development,
(4) ease of manufacturing, and
(5) familiarity of the producer with the class of product..

Quantitative analyses show that goal/strategy, technology/science, and product related information tend to be extremely important for Easy-to-Produce Radicals. These types of information tend to be acquired from richer sources and shared in a more redundant way within the organisation. On the contrary, market, customer, supplier/component, and manufacturing related information is often largely ignored during product development. Development activities are very often restricted only in the R&D function. Functional coupling is rare. R&D people as well as CEO are the key players for NPD information processing and knowledge accumulation. Among all cases, this type of NPD is the one that best uses computers and networking facilities for product innovation. The flow of NPD-related information tends to be directed inward, often to a few key people, rather than to all R&D members. Firms view information and knowledge as vital properties, which should be well organized, safely stored, protected, and utilised by technological elites, i.e., CEO or senior engineers/scientists. The processes and team structures for developing this type of NPD tend to be highly organic, flexible, and encourage self-motivation. However, they are also very technologically oriented. For Easy-to-Produce Radicals, product technology is the most important topic in communication.

10.2.2 Successful Case: DE-650

DE-650 is the world's first commercialised PCMCIA[1] LAN (Local Area Network) card designed for working with computers that have PCMCIA slots. It provides the first real portable solution for laptop or notebook computers, a gateway to the Ethernet Networks. To comply with the standard, the necessary circuit board and components should be squeezed into a flat box of around 2 x 3 x 1/8 cubic inches. Because it is so compact, thin, and small in size, it is sophisticated in design. A highly precise circuit board and electronic components as well as special procedures for producing these components were developed in the laboratory. However, as most circuit designs have been incorporated into modular components, the processes of manufacturing and assembling are straightforward. This product was launched at the end of 1992 and has since been highly successful in terms of both ODM/OEM and self-owned brand businesses.

DE-650 was developed and produced by D-LINK Corporation, a Taiwanese company based at the Science-Based Industrial Park, Hsinchu. D-LINK Corporation was established in 1986 by Mr. Ken Kao with a registered capital of NT$528 million[2]. The corporate mission of this company has been "commitment to connectivity" from the very beginning. Their technological focus is clear; they develop only networking products based on Ethernet and Token-Ring technologies. In the first 4 years of operation, D-LINK was producing standard Ethernet cards, which provided sufficient monetary resource for further R&D on the one hand, and gave opportunities for the company to establish their core technologies around networking products on the other. During 1990 and 1991, D-LINK has successfully developed its first ASIC[3] chip sets that can be used as the "engine" of any networking product. This made Taiwan the second country in the world to own such technology. This was also the turning point that made D-LINK a world-class player of networking products. In 1994, according to industrial reports from Dataquest Inc., D-LINK was the number one producer of Non-Intelligent Ethernet Hubs worldwide, with a customer base of 400 thousand installations and accounting for 15.2% of the global market. For Intelligent Ethernet Hubs and LAN cards, it was listed as 6th and 4th in the league table respectively. The average growth rate of its annual turnover was high, about 60% per year since 1990. By 1994, D-LINK had overseas subsidiaries in 8 countries and more than 200 distributors operating in some 70 countries worldwide.

As highlighted by Chairman Ken Kao, the basic themes of corporate management in D-LINK are "Professionalism", "Accord", and "Innovation", which to some extent are deeply rooted in its highly R&D-oriented corporate culture. NPD has been the core activity of this company. Sales from new products introduced in the previous five years have been the only source of turnover. During this period, about 50 new products have been developed and all were commercially launched, the success rate being about 80%, in terms of whether strategic goals were achieved. Since 1990, annual expenditure of R&D has been about 10% of its annual turnover. By the end of 1993, D-LINK employed about 140 engineers/scientists accounting for around 26% of the total work force in the company, dedicated to new product development. The personnel turnover rate of these R&D people is small, about 4% per year. In addition, the technological core team has been very stable, with only recruitment of new experts into the team and without any resignation of key members since the establishment of D-LINK in 1986.

Before 1991, the corporate R&D structure of D-LINK was a matrix organisation. However, while encountering difficulties in appraising personnel performance and maintaining existing product lines under a matrix structure, R&D function has been reformed into Team Dominant Model (see Chapter 9). One thing is worth mentioning: the director of R&D (the Vice President) is also the man in charge of the manufacturing department. This facilitates the process of transferring results from laboratory to factory. Under such a new structure, R&D function is divided into three sub-functions, i.e., product planning, engineering development, and system development. For the latter two sub-functions, project teams are further constructed based on the Technology Supported Model (also see Chapter 9). The current case, DE-650, was developed by one of the teams under the engineering development sub-function.

Four engineers of the team dedicated to developing DE-650 shared in a room on the second floor of D-LINK headquarters and were supervised by a senior scientist who is an expert in PCMCIA mechanism. Another team member, an engineer from product planning sub-function, who was located elsewhere, was responsible for project control and miscellaneous support. A big round table was installed in the centre of the room. Around the wall were four desks, on each of which computer and networking facilities were provided for team members. At any time when necessary the team members could just turn round to the centre table and have face-to-face discussion, brain storming, or even challenging one another about project details. However, the major medium for communication was through computer networks, e.g., Electronic Mail System. Although D-LINK at the project period had not yet implemented groupware systems for its innovation management, it had effectively utilised network systems for daily operations. All design details, diagrams, and experimental parameters, as well as corresponding technological discussions from project members could be passed through networks to and from the project supervisor. This project-related information was therefore automatically stored in electronic form for later uses.

By 1991 while the standard of PCMCIA had not yet been fully defined, D-LINK had started to study and assess the feasibility of such new technology. One vice president of D-LINK gave birth to the product idea DE-650. In one internal meeting he raised the idea that incorporating all the functionality of an LAN card into a single PCMCIA card might bring a portable solution to network users. Formal LAN cards are often designed to comply with the 8-bit or 16-bit interface card standard, which can only be installed in desktop computers with spare expansion slots. In addition, the installation procedure for these cards is not simple, requiring a certain level of knowledge about computer peripherals to adjust the necessary IRQ and DMA switches[4]. A PCMCIA LAN card can greatly benefit customers in two ways. First, it provides the opportunity for users to connect their portable computers to host or server computers through networking. For example, a salesperson can update the new price list, available product stock, or even an eMail message about new promotion policy from the company's information system directly to his own notebook computer easily and quickly. He can also update the corporate database about his daily sales records directly from his notebook computer. Secondly, it is easier to install the PCMCIA LAN card than the standard LAN card. There is no more need for hardware configuration. As soon as the necessary software is installed, the user can just plug in and play.

However, as in 1991 the world standard of PCMCIA had not yet been fully defined: the selection of correct technical approaches was highly critical. Such a selection must depend on good quality industrial information as well as proficiency of strategic decision making. A formal circulation process across the company for the DE-650 product concept was made to gather a consensus of all functional departments. In summer 1991, the team members were formally assigned and since then all have been dedicated to this project on a full-time basis. In early 1992, while most of the technological problems had been removed and the final prototype had been successful in the laboratory, an American company announced that they had successfully produced the world's first PCMCIA LAN card. However, D-LINK soon found that this was also merely an immature laboratory product. There was still much research to be done before commercialisation. Information from industrial intelligence sources suggested that this American PCMCIA LAN card had encountered great difficulty in reducing defect rates in mass production. In effect this was a problem resulting from poor product design. The D-LINK team worked even harder to refine their product design and manufacturing procedures in an attempt to remove any potential drawbacks in the design for mass-manufacturing. By autumn 1992, results from pilot runs showed an average 50% initial pass rate, reasonable for such a high-end but low-cost product. DE-650 became the first product of its class in the world to be commercialised.

DE-650 has been highly successful in terms of both profit and sales. ODM orders are growing even more fast, providing a great cash flow for the company. After the product launch, the DE-650 team was eventually disbanded. However, two members of the original team were assigned to maintain and support the continual development of this product.

10.2.3 Successful Case: BEHAVIOR Tran

BEHAVIOR Tran is the world's first commercially operated electronic translation machine that can translate English literature into Chinese. Computer Aided Translation is not a new concept. In effect in the last few decades many efforts have been made, as well as resources invested, in this area all over the world, in an attempt to invent and develop feasible translation algorithms. However, it is so difficult to use a machine to replace the brain work ofhuman beings. Very rarely have cases successfully transferred the huge amount of academic studies of Artificial Intelligence, Expert Systems, or Neural Networks, into commercial applications. It is also true that even though some Artificial Intelligence softwares appeared in the market, their "intelligent outputs" were often very poor, or even unusable. BEHAVIOR Tran is a totally different story. It is fast, having an output of 120,000 Chinese characters per hour. Its translation is correct and intelligible. In its successful commercialization, most well-known western computer companies such as HP, IBM, DEC, Microsoft, SUN, LOTUS, CDC, . . . etc. have used it for translating their hardware/software menus, promotion materials, or technological information into Chinese.

BEHAVIOR Tran is a software product developed by Behavior Design Corporation, a Taiwanese company located at the Science-Based Industrial Park, Hsinchu. This product is in effect the heart of a total English-to-Chinese translation solution developed by Behavior Design. Along with other products from the company, the total solution provides automatic English document reading, full-text translation, and Chinese desktop publishing. Input of English text is easy and quick: a "page-feed" scanner[5] and OCR[6] software are used to read a huge amount of full-text directly into the computer for translation. Results of translation from computer can also be directly carried to their own Chinese desktop publishing software for final editing and publishing. As BEHAVIOR Tran is implemented in Unix operation systems, workstation-level computers provide powerful system resources for professional translation. There is no limitation of size in terms of the customisable dictionary. The translation of text is paragraph by paragraph, rather than sentence by sentence. Therefore, the context in which sentences are set is considered during translation. Another benefit of using BEHAVIOR Tran is its ability to deal with graphics, charts, and tables. All these components can be automatically recognised and translated in their original forms.

The core of BEHAVIOR Tran is a set of "Fusion Language" invented by Professor K.Y. Su at the National Ching Hua University, Taiwan. In the early 1980s Professor Su started his long-term investigation of algorithms for machine-based English-to-Chinese translation. Since then, more than 15 of his professional papers researching into this specific area have been published. He has also frequently been invited to give lectures in well known American universities such as UC Berkeley, UCLA, MIT. These academic achievements provided a strong scientific background for the development of BEHAVIOR Tran. Professor Su later became one of two founders of Behavior Design Corporation in 1988. The whole project team was moved from the University to the company in the same year. In 1989, BEHAVIOR Tran was finally mature enough to be applied commercially. The company was therefore started to develop other strategic products that can be used to strengthen the market position of their first product, the BEHAVIOR Tran.

In 1991, their second product, BEHAVIOR d'top was introduced, the first Chinese desktop publishing system running on SUN workstations. In the same year it was awarded US$76,470 by the Science-based Industrial Park in Hsinchu for "Design and Development of a

Grammar Checker Prototype." This Grammar Checker along with a Chinese-English dictionary (i.e., BEHAVIOR Dic) was introduced in 1992, to complete the whole English-to-Chinese translation system.. The IBM RS/6000 version of BEHAVIOR d'top was also introduced in the same year. In the meantime, more projects for supporting BEHAVIOR Tran were initiated. Project teams focusing on OLCR (On-line Character Recognition), Pen-based Computing, and Multi-media products were formed. In 1993, the OS/2 version and the SPARC version of BEHAVIOR d'top were introduced. More alliances with big hardware producers such as IBM, Sertek Technology (Acer), and Twinhead were made for promoting these products.

Behavior Design is still a very young company. However, it has been highly successful and has established its own specific style of innovation management. At first there were only four employees in the company, including the two founders. Six years later, there are 40 people in the company and 25 are R&D engineers (about 62.5% of the total work force). In effect, the percentage of people who directly participate in R&D activities is more than 90%. The turnover rate of R&D people is high, about 40% per year. However, the composition of the technological core team (i.e., the project leaders) has been highly stable since Behavior Design was founded.

The structural arrangement for product innovation is Team Dominant Model. The whole company is in essence a laboratory divided into several groups developing ongoing projects. There are no marketing, sales, and purchasing function in the company. The leader of each project team is responsible for all contacts with customers and suppliers. To some extent they are highly product-oriented. They have never conducted any formal marketing or consumer survey for understanding their current business. They also spend very little in promoting their products. On average around 80% of annual turnover is spent on R&D. They choose "technology" as their strategic focus of operation, and pass over most of the "tedious works" (as they call them), such as "marketing", to their allied companies. They exploit the marketing competence of other companies. Their success is the result of good quality product technology and strategic planning rather than proficiency in marketing or selling.

Since the very beginning of the BEHAVIOR Tran project, the team composition has been highly technology-oriented. Among them, there are algorithm scientists, grammar experts, and software engineers. The team structure is on Technology Supported Model, in which a chief scientist provides necessary supports to the whole team in terms of product concept, detailed product configuration, theoretical background, and reasoning algorithms for constructing the Inference Engine of the product. Most other members in the team are former students of the chief scientist; their responsibility for the project is merely computer programming. Communication among the team is often very rich, direct, and informal, and always focuses on product or technology related information. As this project is software development, mass production for the final product is extremely simple and can be automated. Therefore, it is not necessary to pay too much attention to the acquisition of manufacturing and supplier related information.

The BEHAVIOR Tran team is still operating on a full-time basis continually to improve the current product. However, as the turnover rate of development engineers has been quite high, it is difficult for the team to maintain its knowledge learned from previous experiences. Although computers and networking facilities have contributed much to the reservation of project-related information, a great deal of first hand knowledge has been lost. New members in the team need to be trained before taking responsibility and, therefore, this increases the work load of the chief scientist. This may be one of the most important issues for Behavior Designto tackle, in order to improve NPD management in the future.

10.2.4 Failed Case: Music Faxmodem

It is unfair to use the Music Faxmodem case from ZyXEL Communications to illustrate the negative side of product innovation because this was the only case of NPD failure since the establishment of this company in 1987. However, this case does show how Easy to-Produce Radicals can fail simply because of a faulty approach to innovation management.

Modem (which stands for ***mo**dulator/**dem**odulator*) is a computer device that converts digital signals to and from analogue signals. It allows computer users to link one computer to another over telephone wires. A Music Faxmodem is a modem that not only transfers digital or analogue signals but also recognizes the contents of what it is transferring. In addition to the Faxmodem, which can send and receive Fax messages through telephone wires, the Music

Faxmodem can also send and receive voice as well as music messages between computers. These voice or music messages can therefore be stored as computer files, or be broadcast directly from computers.

Since the early 1980s some Taiwanese firms have started the OEM business of modem products. However, it was not until 1989 that the Taiwanese modem industry started booming. In 1993 Taiwan was ranked the second modem producer in the global market, accounting for about 15% of total world production that year. In 1994, the growth rate of the Taiwanese modem industry was 45%, which, to some extent, reflects the decline of this industry in other leading countries. For example, the pioneer modem maker Hayes was filed for Chapter 11, a US form of receivership designed to protect troubled companies, in November 1994 (Personal Computer World, February 1995).

Among these Taiwanese modem producers, ZyXEL Communications has been the most successful and fast-growing. However, between1987 and 1990, in effect there was no incoming cash flow to this company. During this period there were only seven R&D engineers in the company working hard at researching into the core technologies of modem products, with no salary. By summer 1990 ZyXEL had successfully developed the key component of modem products, the Data Pump, which was originally dominated by the world's leading modem companies such as Rockwell, AT&T, and Sierra. In 1991 the company launched its first product (i.e., U-1496E) and started to make money. This product was also the world's first high speed modem (with 14400 bps transmission rate) complying with the newly established ITU-T V.32bis standard. By 1993 the company was the biggest producer of high speed modem in the world. In 1993 and 1994 it was awarded the title of most profitable (about 40% of profits over sales) high-tech company in the Science-Based Industrial Park, Hsinchu. The work force totalled140 in 1994, of which 22% were R&D engineers. The turnover rate of these R&D engineers was low, only about 2% per year.

Similar to the above successful NPD cases, most product innovations in ZyXEL were highly technology-oriented. Product concepts often spring up from highly sophisticated and long-term scientific researches. Emerging technologies from these researches allow scientists and engineers to anticipate possible future products, in an attempt to evoke customers' future needs. The development process of these new products can often be described as "technology push", in which the product developer is more certain of the availability and feasibility of required technology, while the acceptability of the final product in its focal market is relatively of little concern.

Prior to the case of Music Faxmodem, several products developed by ZyXEL were very successful. Development of these new products was in effect initiated by scientific breakthroughs in the laboratory. This ensured strong technological capability backing these new products. For example, the highly successful Voice Faxmodem introduced in 1992 was in effect a result of the invention of "CELP" technology, which can be used to compress space-hungry voice data to less than 9.6kps and therefore provide the opportunity for voice-based inter-computer transmission. The structural design for managing these product innovations was Network Model, with a very redundant and flexible communication pattern, but strongly technology-oriented.

However, the management of the Music Faxmodem case differs from other NPD of ZyXEL in several ways. First of all, this was a new product initiated from the marketplace rather than in-house R&D. As the main product lines of ZyXEL are communication products, since its establishment the company has provided BBS[7] service to its customers as well as the public. This provided a means for the company to monitor market trends, customer preferences, and to retrieve customer feedback from its existing products. After several years of BBS operation, the marketing people decided that there was an opportunity for Music Faxmodem products. From the marketing people's point of view, Music Faxmodem is merely another enhanced version of Voice Faxmodem. After the success of their Voice Faxmodem in 1992, they believed that it would be no problem to transfer the Voice version to a Music one and make a great fortune.

Consequently, marketing intervention during NPD was more frequent and stronger. Twin Star Model of team management was used for this project. Although the R&D people "felt" that they could handle the necessary technologies, there was no formal feasibility assessment for this new project. On the contrary, a great deal of effort was directed to ensure the acceptability of such a product concept in the marketplace. As expected, the result from the marketing side was promising. The initial configuration, for this product was therefore defined as having the capabilities of sending and receiving electronic messages, including text, image, voice, and music. For voice and music messages this product should be able to recognize a variety of sound file formats and in the meantime reproduce the original sounds through its built-in speakers or other external connections.

Thirdly, no on-the-shelf technology was available for the project. Unlike other NPD in the company that were often triggered by technological achievement, the Music Faxmodem project was "setting goals" first and "finding out solutions" later. This created great technological uncertainties during the development of this product. Some major technological problems such as file format recognition and file compress rates were eventually overcome during in house R&D. However, the quality of one of the key components never achieved its expected standard, which later caused the whole project to fail.

The component that caused project failure was the element for reproducing music/sound effects. Unlike the voice data component that normally uses an 8-bit mono architecture that can be easily reproduced through simple mechanisms, the music data component is much more complicated and requires specially designed chips to handle its output quality. For example, it needs to consider the sampling rates, FM synthesis, wave table synthesis, and even MIDI compatibility. Sound effect is essential to this product. As suggested by an expert in this field,

> *The human ear is incredibly sensitive. The lowest sound level it can detect contains the energy equivalent of a candle on the Moon seen from Earth.*

This product eventually failed after three months of its launch in the US market because of poor sales. A three-month period for products in such a fast-moving industry has proved long enough to appraise new product performance. Consumer opinion about this product said it was "too expensive for such poor music presentation." ZyXEL Communications has never been proficient in multimedia product categories such as sound cards. Their core technology is communication, rather than musical instruments. It may be wrong for them to use a market-led innovation strategy for such a technologically uncertain new product development.

10.2.5 What Can Be Learnt from These Stories?

From the impression given by the cases DE-650 and BEHAVIOR Tran, Easy-to-Produce Radicals seem to be the "Made in an Ivory Tower" style new product development. Project ideas are often initiated from laboratory scientific breakthroughs in an attempt to transfer abstract knowledge into practical applications. For this purpose, the mode of NPD communication is often highly technology-oriented. Technology-based communications within the team are rich and highly redundant. However, the accessing of information is more inward, protected, and focused on gathering information for the few key scientists and decision makers. Computer-based information systems are widely implemented to facilitate such inward information processing. Moreover, as such NPD often regards itself as creating customers' future needs, customer preferences are less considered. NPD teams are often isolated from other functional departments so as to reduce possible interventions from "non-technical" people and therefore increase efficiency of product innovation.

On the other hand, the Music Faxmodem case shows a different mode of project implementation. It was a technologically radical innovation but used a market-led approach for managing NPD. From the beginning marketing people had strong influence upon NPD decisions. The marketing function decided how this product should be designed, without prior formal confirmation about technological feasibility. Information acquisition and transmission were centred more on understanding market trends and customer needs, than a thorough investigation into technology like that of other Easy-to-Produce Radicals. There was higher density of functional coupling between R&D and other disciplines. This made it more difficult for R&D to concentrate on scientific/technological research. Although the resultant product design may be consistent with customers' requirements, the technology embedded in the design may be too immature to produce a good quality product. This suggests that marketing people may be less suitable for anticipating products based on sophisticated technologies. For Easy-to-Produce Radicals, it may be better for disciplines other than R&D to keep a lower profile during product innovation.

§10.3 Hard-to-Produce Radicals

10.3.1 What Can Be Learnt from the Quantitative Results?

According to Chapter Five, Hard-to-Produce Radicals have the following characteristics:

(1) very high profile new products,

(2) high novelty in the marketplace,

(3) high uncertainty at the beginning of product development, and

(4) difficulty or complexity in terms of manufacturing.

As Hard-to-Produce Radicals are difficult or complex in terms of manufacturing, they often require great investment in prototyping and tooling before manufacturing and, therefore, they are more difficult to imitate. To some extent this provides a sort of safety valve that prevents ambitious and skilful employees from pirating product designs and from establishing their own businesses. As a result, Hard-to-Produce Radicals present quite a different pattern in terms of their innovation management.

In general, Hard-to-Produce Radicals are the most information-hungry NPD of all the groups. Statistical results in previous chapters suggest that goal/strategy, market, supplier/ component, technology/science, and product related information tend to be highly important for this type of NPD. These information types tend to be acquired from richer sources and shared in a more wide-spread way within the organisation. By contrast, customer related information is often ignored during product development.

Unlike Easy-to-Produce Radicals, there are some areas of inter-functional co-operation for Hard-to-Produce Radicals. Such co-operation very often is achieved through formal and departmental managerial arrangements such as project monitoring committee or corporate matrix structure for programme management. The processes and team structures for developing this type of NPD tend to be more formal, systematic, and well-defined. Although in some cases there is multi-discipline integration at the team level, technical engineers are ultimately the key players for this type of NPD. The mode of project-related communication is another key point that differentiates Easy-to-Produce Radicals from Hard-to-Produce Radicals. In Hard-to-

Produce Radicals the management style seems to rely heavily on project members for information processing and organisational learning, with openness and trust encouraging information/ knowledge sharing among all team members.

10.3.2 Successful Case: SlimNote586

Although nowadays notebook computers in the Taiwanese market are sometimes regarded as mature products that are no longer high-tech, they still require high investments in technologies for R&D and manufacturing compared with most other product categories. Especially for some high-end notebook computers, technologies embedded in the product design can be very advanced and sophisticated. For example, technologies used in the Pentium[8]-based notebook computers are extremely advanced. On one hand, a real Pentium-based computer[9] should be designed to comply with 64-bit architecture rather than traditional 16-bit or 32-bit so as to take full advantage of the "go-faster" technologies provided by the new processor. On the other hand, a Pentium-based notebook computer should be able to overcome the overheating problem caused by the Pentium processor itself. Unlike desktop computers, which are often equipped with large cases that allow the heat produced by the processor to escape easily, notebook computers are small and compact and therefore increase the difficulty of dealing with the overheating problem.

SlimNote586 from Twinhead International Corporation was the world's first Pentium-based notebook computer. It was first introduced at the 1993 Fall Comdex, the biggest and most influential computer show in the world. At the beginning there were sceptics who did not believe that Twinhead, a trivial Taiwanese company, had such advanced technology to produce the world's first Pentium-based notebook computer. Some competitors even publicly claimed that this product must be merely a prototype, which was still technologically unstable and could not be mass-produced. Such responses from competitors were understandable. In 1993 Pentium processors were still kept in the laboratories of most computer companies around the world for further investigation. The desktop Pentium-based computers had just started to appear. How could Twinhead the minnow over take other big global competitors in notebook computer products? However, facts are more convincing than eloquent theories. SlimNote586 has been extremely successful in sales. Consequently, in 1994, Twinhead for the first time became the market leader in Taiwan in notebook computers. In the same year, Taiwan also for the first time rose above Japan and took the lead in the global notebook computer market, with an annual production of some two million sets or 28% of world total output.

Twinhead International Corporation was founded in 1984 and initially specialized in ASIC design and the production of computer add-on-cards. Through the early years it established a reputation for developing low cost, but innovative, ASICs for local computer firms. This early R&D into ASIC gave Twinhead strong technological competence, while developing other electronic systems. In 1987 it expanded into PC (personal computer) systems manufacturing, offering OEM products to some global computer leaders, such as Wang, Unisys, and NCR. By 1989, Twinhead had become one of the major PC manufacturers in Taiwan, and in the mean time, started to invest in R&D for portable (laptop) computers. The top management of Twinhead intuitively decided that "mobility" should be the key feature of next generation personal computers. At the time this was a brave and risky decision involving heavy investment into both the technology and marketplace. As one of the senior managers stated in the interview, "We believe it will be the future, and we go for it!"

However, its very first attempts into the portable computer market failed. Like other novice firms moving into this product category for the first time, it encountered difficulties in dissipating the heat generated by the computer processor and in porting the LCD (Liquid Crystal Display) into the system. Luckily, based on their previous expertise in ASIC design, in two years researchers at Twinhead had successfully found solutions for overcoming these key difficulties. In 1991, the first Twinhead notebook computer rolled out of the factory and, since then, Twinhead has won a reputation as the notebook computer specialist in the industry.

The total number of R&D engineers at Twinhead is 80 at the time of this study, accounting for about 10% of the total work force. From the beginning, research into the heat dissipation problem of notebook computers has been one of the major items in Twinhead's R&D. Several senior engineers were assigned to an engineering support team to investigate this kind of technical problem. Besides the engineering support team, the whole R&D is divided into two sub-functions, i.e., electronic design and system design. Project Committee Model as described in the last chapter is used for corporate NPD management. By operating on a weekly basis, this multi-discipline committee defines the directions of future R&D strategies as well as detailed configurations for current NPD projects. Nomination of team members to NPD projects is another major task of the committee, where engineers from each sub-function are assigned under a matrix arrangement. Although it is normal for marketing people to join NPD teams, the composition of teams is in effect highly technologically-oriented. This is because all marketing people (including the managing director of the marketing department) are basically former R&D engineers who have had little background or training in marketing. They are often very sensitive to the technological feasibility of projects rather than to the understanding of customer needs.

The model for managing SlimNote586 project was a combination of Technology Supported Model and Matrix Model (see Chapter 9). There was high intensity of communication among team members. However, integration between functional departments was relatively rare. Within the team, a PM (programme management) and a PP (product planning) manager were assigned from the marketing department to support project scheduling and to maintain the consistence of product concept during development. Other members in the team included an electronic engineer, a system engineer, a software engineer, an engineer for technical supports, and the project leader who had expertise in dealing with critical problems in designing notebook computers. Communications among team members were rich, direct, and highly redundant in terms of discussions about technologies, product design, and availability of suppliers/components. Secondary information about market trends and competition activities was provided by the marketing department on a regular basis. All members were allowed to access any portion of project-related information.

In general, there were several ingredients for the success of SlimNote586 project. First of all, early investment in portable computer technologies provided strong technological capability for developing high-end notebook computers. This relied on sharp and correct intuitional decision making and fast and powerful strategic moves. The commitment from top management was clear: "The mobility of the personal computer is the future and, therefore, why not a Pentium-based notebook computer?" Secondly, strong technological competence was highly necessary for this project. Since the years of doing ASIC design business, Twinhead has established a good system for reserving technological knowledge, i.e., information sharing as organisational learning. Although the average turn-over rate of Twinhead R&D engineers is about 10% per year, sharing project-related information between all R&D members makes the inheritance of knowledge possible. Thirdly, technology-oriented rather than customer-oriented corporate culture and managerial arrangements motivated Twinhead to create customers' future needs rather than to fit customers' current requirements. This was risky, but results were fruitful. Finally, the proper uses of NPD management structure and process models contributed much to the project success. For Hard-to-Produce Radicals, a more systematic approach to R&D may be more appropriate for project management.

10.3.3 Successful Case: ScanMaker III

ScanMaker III from Microtek was the world's first (and during the survey period the only) PC-based 36-bit colour flatbed scanner that can handle up to 68 billion colours in a single touch. Scanners are peripherals which convert paper-based images (e.g., text, photos, illustrations) into computer files and these files can therefore be manipulated by painting softwares or published through desktop publishing systems. The once highly craft-oriented colour separation shops have gradually been replaced by new technology-driven and market-sensitive computerized scanning. Today, electronic colour scanners do more than 98% of colour separations in the American graphic arts industry. According to the industrial forecast from Market Intelligence Research Corporation, revenues from colour desktop peripherals and copiers will be over US$13 billion in 1997.

However, professional applications of colour scanners for industrial-grade production[10] were often very expensive and were formerly only available in the workstation platforms. For example, the scanners used in professional Colour Electronic Prepress Systems (CEPS) could be very costly, with an entry-level price of US$35,000 in 1993. On the contrary, low-cost desktop colour scanners normally aim at other market segments. Their resolutions range from 200 dpi (dots per inch) to as many as 1200 dpi with a price band from less than US$100 to US$5,000. The quality of their output is not perfect, but they are cost-effective. On many occasions these units are still very useful and have produced impressive work. Especially when more multimedia, spreadsheet, database, and word processing packages begin to be equipped with the ability to store and manipulate colour images, these low-end colour scanners become increasingly popular in the marketplace.

Unlike the normal colour flatbed scanners crowded in the low-end product segment, ScanMaker III creates and penetrates a new segment between the high-end and low-end scanner market. It is made to comply closely with the professional industrial-grade standard of colour scanning but also maintains a highly competitive price compared to conventional flatbed scanners. In effect, the list price of ScanMaker III is amazingly competitive, around US$4,500 in 1994.

Key differences that separate ScanMaker III from other flatbed scanners are the capability of optical resolution and pixel depth of scans. ScanMaker III provides 36-bit colour depth with an optical resolution up to 1200 x 1200 dpi. The best of other flatbed scanners only offer 24-bit colour palettes, capable of handling 256 shades at most between the extremes of each colour. While 256 shades may look enough, the range for graduations and saturations can easily run out. The resultant output is usually poor highlight or shadow detail. To get rid of this problem, the most professional industrial-grade colour scanners use a much higher colour depth, e.g., 36 or even 48 bits per pixel, to handle colours. Of course, softwares for manipulating the scanned results or printers for reproducing the images may not support full 32-bit colour depth. The point is that the capability of higher colour depth provides opportunity for users to choose which 24 among the 36 they will use, and these may not necessarily be the 24 most significant bits.

ScanMaker III was developed by Microtek International Inc., a Taiwanese high-tech firm based at the Science-Based Industrial Park, Hsinchu. This company was founded by Bobo Wang in 1980 with four other fellow Californian Taiwanese. In the early years of Microtek, MICE

(Micro In-Circuit Emulator) was the only product to provide necessary funding for supporting its R&D. Even today, sales from MICE still account for about 15% of its annual turnover. In 1984 Microtek was among the few pioneers in the world (and the only one in Taiwan) to produce scanner products. Today, Microtek vies with Hewlett-Packard (HP) for leadership in image scanners. HP still dominates gray-scale scanner products, but Microtek takes the lead in the colour scanner market. In effect, in 1994 Taiwan was the second biggest producer of scanner products in the world. Especially in the area of handy scanners, Taiwan was the leader in the world market, with about 80% of the global market share.

The capability to popularize quickly highly radical technologies into low-cost applications has long been the source of Microtek's competitive advantage. From the beginning of doing scanner business, "to provide low-cost solutions of high-end products to the common user" has been a norm for Microtek's R&D. For example, in 1989 Microtek launched its first colour scanner at a price of US$3,000, while the same class of products sold by such competitors as Nikon and Sharp was US$7,000. Another example was the introduction of the colour slide scanner in 1991, with the capability of handling 35mm slides and this was priced at one third the cost of existing models. DCR (Dynamic Colour Rendition) technology[11] once only used in the most high-end professional scanners was also popularized into all Microtek's flatbed scanners, free of charge. Its competence in implementing high-end technologies at a very low cost is the most powerful weapon Microtek has to take over the market share from its counterparts.

Maintaining such a technological competence rests on good management of R&D. However, in the Microtek case there is a paradox worth discussing. In the previous five years the average ratio of R&D expenditure to annual turnover was about 12%. During the period, 20 NPD projects were implemented and 90% of them have been successfully commercialized. The R&D activities of Microtek are located in three countries, i.e., Taiwan (the major R&D base with seven laboratories), USA (two sites), and mainland China. The total number of R&D people is about 100, roughly 20% of the total work force. One thing is noticeable; while turnover rates of junior engineers remained very low (nearly zero) in recent years, senior/chief engineers in the core team have suffered very rapid turnover. In effect about 90% of key members in the core team have changed since 1990 when its company bonds went public in the Taiwan financial market. Two things bore the blame. First, because Microtek implements a stock sharing policy, all members held company bonds before it went public, and the amount of stock depended on the tenure and the contribution of the person to the company. The more senior (and of course the more important) a person in the company, the more the stock s/he was granted. Secondly, because the financial performance of Microtek had been so outstanding, with an average gross profit of 70% in the 1980s and 40% after 1990, the market value of company bonds largely exceeded their book value. The making public of company bonds in 1990 provided an opportunity for the stock holders to earn money from selling their company bonds, and very quickly created a handful of billionaires. In the meantime, most of those "newly-rich" who resigned from Microtek started to establish their own businesses in competition with their previous employer.

One remarkable case was the establishment of Must Systems Inc., which has been the leader (dominating 35% of the global market) in the world Handy Scanner industry. Another case was the Umax Corporation, also a leading Taiwanese scanner company and perhaps the largest in terms of annual production, which directly competes with Microtek in the flatbed scanner market. Microtek was beaten firmly by its former fellow employees. However, it still takes the lead in terms of technological competency. As the technological core team of Microtek was nearly destroyed, it is interesting to know how this company can still maintain its technological leadership in this industry.

Microtek uses Matrix Model for managing its corporate-level as well as team-level R&D. Although in its organisational hierarchy there are two committees responsible for corporate-level operations, the R&D department officiates at all NPD-related activities. However, the differentiation of these two committees does show great influences upon patterns of functional interactions. Marketing function has been put under the supervision of the Executive Committee, in which a Business Planning Centre is formed to provide market-related information to the whole company on a regular basis. Another committee called the Product Strategy Committee supervises R&D and Manufacturing functions. As a result, the relationship between R&D and manufacturing people has been quite close, while marketing people are relatively isolated from technicians. The interface between marketing and R&D is the Business Planning Centre which is somewhat indirect and formal in terms of functional communication.

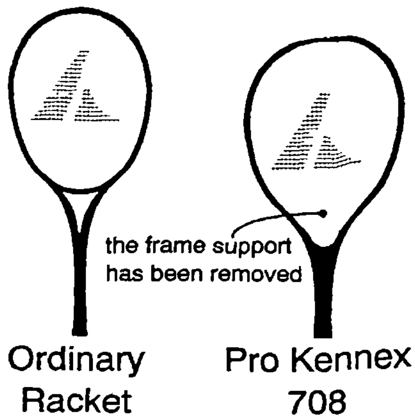
Along with such a structural design, the concept of "sharing" has been highly promoted. For example, in the early days the sharing of company bonds with all employees drove R&D engineers to work hard into the night, seven days a week, for many years. More importantly, it is the sharing of information and knowledge between all R&D members that distinguishes Microtek from other Taiwanese companies. There is extensive computer networking for creating, communicating, accessing, and accumulating project-related information. There are also plenty of technical seminars for knowledge sharing and brain storming between R&D members. The quality of technological documentation is excellent and has been carefully accumulated since the beginning of the company. There is free access for all members to any kind of information, including files, drawings, and experiment results in the computer system. This is why Microtek can preserve its previous knowledge through the years, regardless of very high turnover rates of key engineers in recent years. However, this is also the main reason why its former employees can so easily turn into strong competitors. The concept of "sharing" is two-sided. On one hand it created Microtek's technological competency and financial excellence for many years; on the other hand, it also caused the corruption of Microtek's core team and produced even more formidable competitors in the marketplace.

The development of ScanMaker III followed the same path as Microtek's other high-tech products. First of all, it was technologically-oriented, although a great deal of information about market trends was necessary to decide product positioning, system specification, and pricing policy. Only R&D people were involved in NPD, including system engineers, software engineers, electronic designers, mechanical designers and optical experts. During NPD, the project leader held stage reviews twice a week in an attempt to integrate each individual's work. However, more communications among members were undertaken through computer networks as well as face-to-face interactions. Secondly, there were very few interventions from marketing function during product development, except for the provision of market-related information. Meanwhile, R&D people also took very little interest in how marketing was operating. Thirdly, there were only intuitional guesses about customer needs and behaviours, rather than formal investigations. They believed that they were evoking customers' future needs and meanwhile creating a totally new market segment. Finally, although the relationship between R&D and manufacturing was quite friendly and close, the manufacturing function in effect had very little influence upon R&D. They rather passively accepted manufacturing drawings issued by R&D in the later stages of NPD. R&D team members therefore need to spend more time accompanying manufacturing people in the first few shifts of mass-manufacturing.

10.3.4 Failed Case: ProKennex_708

ProKennex 708 was a tennis racket developed by Kunnun International Holding Ltd., known as ProKennex International Inc, in 1990. It was a specially designed tennis racket, the lightest in the world at the time it was launched. There were two revolutionary concepts behind the product design, both resulting from long-term observation of consumer needs. First, ordinary rackets are heavy, which can easily weaken the power of strokes after a long period of stalemate. However, reduction of racket weight can lead to an increase in vibration, and a reduction in the strength of the racket frame. In addition, the frame of ordinary rackets is relatively small, which influences the stroke rate and therefore reduces the fun of playing tennis. However, increasing the frame size means adding additional weight to the racket, which is also not favoured by racket developers. Such technological difficulties prevented former producers from making light-weight, large-frame rackets. By removing the frame support that is usually compulsory to normal rackets, and by using lighter and stronger material for constructing the racket frame in a special way, ProKennex believed that they could produce a racket that satisfied both requirements.

Established in 1962, ProKennex is the world's leading company specialising in sports goods, such as tennis, badminton, and squash rackets, golf club heads, hockey sticks, and sports bicycles. The core technology of the company is material science, especially in the area of compound materials such as carbon fibre. ProKennex is particularly well known for its tennis racket products. Although the company is no longer the world's leading producer of tennis rackets, it has established a reputation for providing the most advanced products in the industry.



For example, in 1991 it launched the world's first "asymmetrical" racket which provided the best performance for reducing stroke vibration. In 1994 it introduced the very high-tech Kinetic racket, also known as the "racket of the 21st century", a racket that has loose metal particles inside the frame around the head to release any possible vibration and provide maximum control.

In the previous five years, the company had an average ratio of R&D expenditure to annual turnover of about 3%. During the same period about 150 NPD projects were undertaken, of which 60% were commercialized. Meanwhile, of the commercialized new products, about 80% were considered successful. However, most projects were merely incrementals, which required only one month or a half to carry out. The Functional Model is used for corporate R&D management. During the survey period, there were 18 people in the R&D department, accounting for about 1% of the total workforce. Two key people in effect handled all major NPD tasks, i.e., (1) the chief scientist, an expert in compound materials with a Ph.D. degree in chemical engineering, and (2) the head of R&D, a specialist in styling and structural design. Other R&D members were merely technical assistants for the above two key people. A small scale production line was set up in R&D, which provided R&D with the power to implement the whole process of product innovation independently, from idea generation down to pilot run. All NPD were conducted in-house; however, for some highly novel projects, they did maintain close links with domestic as well as overseas technological/scientific research institutes. For example, the Kinetic racket launched in 1994 was the result of a three-year research conducted by a German physicist, Dr. Roland Sommer, with the support of ProKennex.

As with most radical projects, the involvement of external experts in defining and developing necessary technologies was normal for ProKennex; furthermore there were extensive validations for prototypes in terms of scientific tests in the laboratory as well as usability tests by professional tennis players under special agreements. However, by departing from its traditional NPD approach, the ProKennex 708 project used a more independent and somewhat ivory-tower style development method. The Super-charged Designer Model was used to develop this product. Although the basic product concept was provided by marketing function, the major efforts of product development were conducted inside R&D. Based on their expertise with compound materials, accumulated through previous years, R&D people had confidence (or, over-confidence perhaps) about the technological requirements for this project. In addition, they proposed a new material as well as a new process design experimentally.

From the beginning, ProKennex 708 was defined as a short racket without a frame support. It should be light, with a large frame, and to some extent vibration-free. The aim was to reduce the weight of the racket and more importantly increase the size of "sweet spot". The material employed in constructing the racket frame was carbon fibre, a light and strong material, widely used in Aerospace industry. The conventional method of using carbon fibre is to draw and wrap the fibre, layer by layer, manually. The intersecting angles and skills for wrapping these fibre layers are therefore industrial secrets which decide the strength of the resultant material. However, such a process is slow and tedious, and is not suitable for machine-based mass-production. ProKennex 708 took a different approach. By using a special machine designed in-house, carbon fibre was jetted on to a model and was formed as long tubes. These tubes were later used to make racket frames.

Preliminary results from laboratory experiments looked promising. Stress tests suggested that the resultant prototype was strong enough to endure strokes. Structure design was also excellent, with a minimum vibration level compared with other rackets. However, as ProKennex was so confident of its technological competence in this project, no further scientific analysis was undertaken to assure the validity of these preliminary tests. To some extent, the whole development process was based on the pure imagination of two key R&D people, although the final product eventually passed through pilot run and went into mass-production. This product failed about two months after its launch, due to complaints from the first customers concerning frame distortion. The racket frame was not strong enough to endure continuous smash and return. High temperature was another reason for the frame shape's twisting; in sunny weather such a racket frame cannot maintain its shape if it is kept in the car boot for several hours. Finally the production line was forced to close, resulting in a total loss of about US$5 million.

10.3.5 What Can Be Learnt from These Stories?

As highlighted by the cases SlimNote 586 and ScanMaker III, Hard-to-Produce Radicals tend to be R&D initiated projects aimed at applying highly advanced technologies to practical products. Similar to that of Easy-to-Produce Radicals, product technology is the major concern of information acquisition and communication for this NPD type. However, Hard-to-Produce Radicals seem to be more information-hungry. They tend to allow a certain level of intervention from other non-R&D functions, although R&D is still the key player in NPD. Such functional coupling is often achieved through formal organisational arrangement at corporate-level, and is often limited to the head of each department only. Highly redundant information sharing within R&D is a distinct feature of successful implementation of this NPD type. Project-related information is more freely circulated across all NPD teams and all members in R&D. In effect, they tend to rely heavily on all team members to process information and accumulate experiences, rather than on one or two key individuals.

ProKennex 708 used a different approach to manage NPD. It was not a R&D initiated project aimed at applying technological breakthrough to a practical product. Although it was also not a market-led product development, its understanding of the focal marketplace was far beyond its actual capability to find the necessary product technology. Furthermore, unlike other Hard-to-Produce Radicals that are often very keen on information processing, this project seemed to have less information needs. There was very little functional coupling during NPD. The mode for information transmission during development also tended to be inward, narrow, and centred on the chief scientist/decision makers only. Other R&D members were treated merely as project assistants, without heavy involvement in NPD information sharing. As a result, the whole project was totally led by two key individuals without incorporating knowledge/experiences from other fellow members. Therefore, this project was highly risky. For Hard-to-Produce Radicals, competency in advanced technology, enthusiasm for information acquisition and processing, and a special commitment to highly redundant within-team information sharing, may be the most important keys to project success.

§10.4 Untried Incrementals

10.4.1 *What Can Be Learnt from the Quantitative Results?*

Untried Incrementals are often those NPD that imitate or modify existing products from other market segments. In some cases, they are also possibly incremental diversifications by companies into other product categories that they have never tried. Based on Cluster Analysis discussed in Chapter Five, this type of NPD has the following characteristics:

(1) low product profile but novelty in the focal marketplace,
(2) low uncertainty at the beginning of product development,
(3) minor difficulty in manufacturing, and
(4) the firm is unfamiliarity with such a product development.

Similar to Easy-to-Produce Radicals, in general, this type of NPD shows less enthusiasm for information processing. Quantitative analyses suggest that product and technology related information are highly important to this type of product innovation, while customer, cost, and manufacturing related information to some extent are regarded as less necessary. They also tend to transmit suppliers/components related information in a more redundant way, although they regard such information as not very critical. Most types of information transferred during NPD are somewhat direct and informal, which suggests that there are very few serious or large-scale information searches for product innovation. In effect the major channel for NPD communication is through personal relationships of members in different functional departments.

For Untried Incrementals, the CEO often plays a more important role in product innovation than for other NPD types. As this type of product innovation is a kind of diversification into unfamiliar product categories, CEO often presents a higher level of participation during NPD. It is also possible for CEO to take charge of product innovation for this NPD type, although all NPD activities are in effect implemented inside R&D. In addition, there is close functional integration between R&D and other functional departments. Compared with other NPD types, team composition of Untried Incrementals was more diverse too, the highest proportion being marketing and some manufacturing people. The major means for reserving NPD knowledge are through good documentation as well as keeping key people in R&D. In general, Untried Incrementals are not very keen to process NPD-related information; however, they do provide intelligent mechanisms for team-level or person to person information transmission. By mixing people with different backgrounds and disciplines in a more direct and informal fashion, it is not really necessary for any other formal arrangement for corporate-level functional communication.

10.4.2 Successful Case: Papaya Milk

Fresh papaya juice is a popular beverage for the Taiwanese. Traditionally it is served as a mixture with milk, ice, and sugar, in a 500cc tumbler. The Taiwanese call it "Papaya Milk". Especially in the summer time the Taiwanese love to enjoy one or two tumblers of papaya milk during the daytime to escape temporarily from the hot and thirsty sub-tropical weather (normally the temperature is above 30°C). However, papaya juice deteriorates very easily. A special substance (a kind of hydrolytic enzyme) in the juice quickly turns papaya juice bitter when stored overnight, even in a refrigerator. As a result, the enjoyment of fresh papaya milk was highly restricted to the (papaya) season; it was inconvenient to serve (one needed either to find a café or prepare the juice oneself); it was not always available (e.g., at midnight), and it was almost impossible to achieve consistent quality in each serving.

Vacuum-packed papaya milk was first developed and produced by President Enterprises Corporation, the biggest food company in Taiwan. During 1988 after a series of investigations into papaya juice, scientists in the Central Laboratory of President Enterprises finally identified and abstracted the substance causing deterioration. Subsequently they developed a standard procedure for separating such an enzyme from the juice and therefore made the development of vacuum-packed papaya milk possible.

Founded in 1967, President Enterprises established itself as a trading company of mass supplies with an initial capital of merely NT$30 million. Today its annual turnover has become more than NT$20 billion and the firm has diversified into a variety of industries such as food, banking, and chain stores. It also owns the largest R&D department with the highest annual R&D expenditure in Taiwan food industry. The R&D department in President Enterprises is called the Central Laboratory, where 118 people (including four Ph.D.s and 60 MSc.s) are employed in product innovation. Annual R&D expenditure is around NT$0.22 billion, which is roughly equivalent to 1% of annual turnover. During the survey period, the focal interests of the Central Laboratory were still directed on product development rather than scientific research, although by the end of 1994 a sub-function in the laboratory was established exclusively for conducting basic scientific research. In the previous five years about 300 NPD projects were undertaken in the laboratory. Among these, 25% were applied researches, 35% were product developments triggered by R&D people, and 40% were market-led product innovation. About 90% of these R&D efforts have actually reached their focal market. However, only 30% were regarded as successful.

President Enterprises takes a unique bifocal approach to corporate-level innovation management based on the Project Committee Model. There are two types of Project Committee in the company. According to the organisational hierarchy, the highest level of Project Committee (i.e., R&D Committee) deals with the most important and expensive projects that require special commitment from the executive board. This committee consists of 15 decision makers from all SBUs around the company and is directly supervised by the CEO. The second type of project committee is the NPD Promoting Team at SBU level, where the managing director of each SBU and all functional managers in the SBU form the committee for screening, recommending, and planning all SBU-owned R&D projects. The latter type of committee works closely with scientists/engineers in the Central Laboratory and meanwhile acts as an interface for functional coordination.

The original product concept of the Papaya Milk project was initiated by marketing people. Based on informal observation, the marketing people felt that there was a huge domestic population who regularly drink papaya milk in the summer. A vacuum-packed papaya milk that can be served at any time, in any situation, and can be mass-produced with a standard quality, could benefit customers on one hand and bring great fortune for the company on the other. After initial discussions with the R&D people, these marketing people gave a proposal to the NPD Promoting Team and requested a formal assessment from the R&D department concerning the technological feasibility of this product concept. However, at that time the company had no feasible technology nor experience to handle the deterioration problem of papaya juice. In effect they did not even know the cause of such a problem. In early 1988 the Central Laboratory decided to investigate the chemical composition of papaya juice. The Papaya Milk team was therefore formed and started its R&D efforts.

Informal inter-personal communication, rather than formal functional information transmission, played the key role in developing the Papaya Milk project. The team management approach for this project was based on the Twin Star Model where interactions of members between R&D and marketing were high. Although there were formal communications between the two functions, frequent inter-personal interactions in the hours after work made it much easier for project members to share and integrate ideas from both technology and marketing. They ran a "Happy Club" (see Chapter 8) for after hours social activities such as pub-crawling or playing tennis in an attempt to facilitate communications between these two functions. By the end of 1988 the substance that causes the deterioration problem of papaya juice was identified and the separation process for such substance was also developed. R&D people started to work closely with marketing people in defining the attributes of the resultant prototypes. For example, in their after-hour "happy club", the marketing people were allowed to try out all the new tastes of papaya milk which had just been produced right from the laboratory. Because of the extensive interactions between both sides, the resultant product quality developed by R&D people was highly consistent with the initial product concept from the marketing function. In 1989 when such a vacuum-packed papaya milk was launched into its focal market, consumers were soon attracted by this "new" but traditional product. As a result this product has been highly successful in its domestic market. It is still the market leader today, even when several competitors have also resolved the deterioration problem of papaya juice and provided similar products at lower prices.

10.4.3 Successful Case: N-Notes

Yellow Stickies, or self-stick removable notes, are a very popular item of stationery in today's offices. They were first developed by an American company, 3M, during a laboratory incident. Today, five companies in the world own the technology to produce such a product; however, 3M still dominates about 96% of the global Yellow Stickies market. USI Far East Corporation (USI) is among those companies (and the only non-American company) that produce Yellow Stickies. By 1993 it was the second largest supplier of such a product in the world, with a global market share of about 3%. Yellow Stickies produced by USI were called N-Notes, denoting that they can be stuck and removed for as many as N (an infinite variable) times. Unlike 3M which can only extend its Stickies product lines in terms of different sizes or colours, USI provides more options for Stickies products, such as sticky carbon papers, sticky art papers, and sticky recycled papers. For these product line extensions, USI takes the lead in the world's market as it was a spring-off company from the biggest paper company in Taiwan. This means that the company owns sufficient technology to develop paper-based products.

Founded in 1974, USI established itself as a specialist in producing specific-purpose chemicals for the paper industry. Today, USI not only specializes in chemicals for the paper industry but also penetrates other industries such as pharmacy, electronics, and pollution prevention that require specific-purpose chemicals. However, the major competence of this company is still in chemical products for the paper industry. In the last 20 years more than ten core technologies centred on paper-making chemicals were developed. Although these core technologies are not actually the most high-end ones in the world, USI has been highly proficient in strategic hybrid innovation, i.e., by intelligently combining different technologies into one product innovation. As stated by the CEO (also the managing director of R&D), Dr. Kuo, in an interview,

> *It is not very critical to pursue technological leadership in the world market; the key point is how to combine these technologies into a profitable product.*

USI uses the CEO Dominant Model for managing corporate-level R&D. As it happens, the CEO himself is an expert in chemical engineering. He participated in most of the research work for developing these core technologies. As there is strong commitment from top management to support product innovation, this company to some extent is highly innovative and risk-taking. Annual R&D expenditure over turnover is about 10%, while new products launched in the previous five years have contributed to annual sales and profits with about 25% and 75% respectively. "Three new products per year" has been a slogan for USI's new product development, although in effect at any time about forty projects are undertaken simultaneously. To maintain such a high competence in product innovation, USI uses a special overlapping approach to project management.

USI uses the Network Model for NPD team management. For each core technology domain, a team is formed to continue the necessary scientific researches as well as product development. Each R&D member is assigned to one or several of such teams based on his/her technological background and previous R&D experience. Incentives are provided to support such an arrangement. One key factor in assessing team performance is the diversity of team composition; with the same development results, the team with more multidiscipline members participating in the task enjoys a higher monetary reward than does the single discipline team. As a result, most NPD teams in USI are highly cross-functional, in which members with special technological capabilities as well as from other functional departments may possibly be invited to join the team, depending upon the requirements of the project.

As there is a high level of overlapping of members' responsibilities among project teams, the authority and responsibility of each member are somewhat vague, which increases the difficulty of R&D management. However, in the meantime, such a managerial arrangement also brings the flexibility of manpower utilisation and the opportunity of knowledge sharing and learning among all R&D members. The spirit of team work is greatly encouraged. Moreover, such a Network Model of team management provides a major benefit in that it facilitates hybrid innovations. Every R&D member in USI has the opportunity to participate in one or several core technology developments simultaneously; this increases the chance of blending different core technologies in a single project.

For example, N-Notes was a hybrid NPD that combined three core technologies into a single product. The team included R&D people, marketing people, and even research fellows from key suppliers. All NPD activities were undertaken in the R&D department. Communications within the team were rich and frequent; however, during NPD there were few interventions from other functional departments in terms of requesting or providing project-related information. As N-Notes was not really new in the world market, it was easy for the team to learn from its major competitive products. The developers could also be the users of existing competitive products, which eased the validation process of the final prototypes. The key difficulty of this project was merely the technological know-how of material application rather than uncertainty in the marketplace. As soon as the technical problems were sorted out by chemical engineers, this product was destined to success.

10.4.4 Failed Case: HPB-I

HPB-I was the first office wire/comb binder produced by a Taiwanese company. It was designed to punch and bind A4 pages into stylish and easy to read documents in simple steps. However, with the lack of necessary technology as well as experience for such product development, the first attempt at this NPD project failed owing to the unstable binding quality of the final product.

The wire/comb binder provides a portable solution for office and personal document management. It is a desktop size machine that can punch holes in a stack of papers and in the mean time bind these papers by using wires or plastic combs. Although at first glance the mechanism for such a binding process is simple, the construction of this machine to some extent is complicated. The key technological barrier to designing and producing such a machine is the difficulty of maintaining good punching quality while keeping the whole system light. Wire/comb binders should allow several holes (i.e., 21 holes as standard) to be punched into a stack of papers in one punch, but a light-weight system weakens the force of each punch and therefore reduces the capacity (i.e., thickness and volume) of papers that can be handled at any one time. In addition, as the position and dimension of the holes should be correlated with existing industrial standards of wires and plastic combs, the size of each hole and the spaces between have to maintain a cer-ain level of precision. A light weight system increases the opportunity of punching imprecise holes.

However, a portable wire/comb binder should also be designed as light enough to be carried easily around the office. To maintain the balance between portability and punching and binding quality is therefore the major challenge in product development. It requires good quality components as well as good system structure so as to provide precise and sufficient punching force from the light weight design.

HPB-I was the first try at developing office wire/comb binders by Dah Hsin Industrial Corp., the world's biggest producer of raincoat, slicker, and rainboot products. As the raincoat products were often highly labour-intensive, the production of such products was very sensitive to the nature of the local labour market. In the early 1980s when Taiwan gradually transformed itself into a richer country, the CEOs of Dah Hsin saw a risk that they might quickly lose their market leadership with their existing product lines due to the increasing of local labour costs. To strive for survival, this company decided to move their existing low-end production lines to mainland China (PRC) where the labour cost was one twentieth of that in Taiwan. In the meantime, they kept a few production facilities for manufacturing high-end products and maintained an R&D centre for new product development. More importantly, they believed that it was urgent for them to diversify into other product categories based on their original technological competency, i.e., plastic technology.

By the mid-1980s this company had successfully introduced its plastic wire and plastic comb products for binding machines. A new R&D task force was needed to help the company penetrate into the officeware industry. The first product on the schedule was a wire/comb binder, with a code name HPB-I. Based on Functional Model of corporate R&D management and Super-charged Designer Model of team management, this task force permanently kept to its own office and was isolated from normal corporate operation. The composition of the team was straightforward, seven machinists and one electrical designer. There was no intervention from other functional departments during NPD as this project was a new venture for the company and was financially independent; also, other functional departments had no knowledge of such a product class and, therefore, had no influence on the project team.

As this company initially had no knowledge and experience of producing such a product, the effort of re-engineering was important for learning the necessary technologies of system design. Re-engineering is a process of looking into the design secrets of competitive products by dismembering and reconstructing existing products. To learn the basic structure and operation mechanisms of the product, the HPB-I team studied several wire/comb binders from competitors and formulated its own system design. However, as the composition of the team was very single-discipline, there was no early warning about the technological feasibility of such a system nor about customer preferences. In particular, potential technological problems such as the use of materials for constructing components and the stress balance among components were totally ignored. There was also no scientific calculation of the cutting force produced by each punch upon the papers; therefore, it was not possible to estimate the capacity and usability of the resultant machine. Even worse, no manufacturing people joined the team during NPD. Eventually all parts were designed in-house but produced by external contractors. As these external contractors had no knowledge of the initial design concept, the quality of tooling and manufacturing of these components was highly questionable. The resultant product was imprecise and unbalanced in punching holes because of poor design.

Obviously there was no chance of success for this product; it was poor in quality and with no consideration of customer needs. Fortunately, Dah Hsin quickly learned from such a failure and re-organised its team structure by allowing participation from other disciplines such as marketing and manufacturing during product development. Today's Dah Hsin is the world's third biggest producer of office wire/comb binders. Most of its subsequent successful models of wire/comb binders were initiated by marketing people. For example, the very compact personal wire binder introduced in 1992, the HPB-123, was an excellent best-seller, originally conceptualized by marketing people. Success is never far away, if one has the know-how.

10.4.5 What Can Be Learnt from These Stories?

The Papaya Milk case and the N-Notes case demonstrate how successful Untried

Incrementals manage NPD information processing. Untried Incrementals tend to process information in a flexible and informal way. They tend to devalue the necessary formal functional coupling, but maintain rich and frequent multi-discipline communications/integrations through inter-personal channels within the formal organisational structure. Multi-discipline team composition is common. Marketing people often work closely with R&D. However, the new product development is product-oriented, rather than market-oriented.

On the contrary, the HPB-I case shows quite a different pattern of NPD information processing. In this case, the team composition was a highly single-discipline one, providing very little opportunity for multi-discipline information sharing and learning among team members. Moreover, this team was isolated from other functional departments in the organisation. There was not only no formal coupling between the team and the rest of the company, but also a lack of informal communications between team members and "outsiders". As a result, the team easily fell into an "Ivory Tower" style product innovation, which decided the unfortunate result of this project. For Untried Incrementals, a flexible and informal arrangement for multi-discipline interaction/integration during NPD may be very necessary to ease learning and the sharing of low novelty, but unfamiliar, knowledge among team members.

§10.5 Tried and Tested Incrementals

10.5.1 What Can Be Learnt from the Quantitative Results?

Tried and Tested Incrementals are those minor product improvements or engineering changes to existing products. By using on-the-shelf technologies, the key issue of such NPD is therefore the fulfilment of current demands, rather than creating customers' future needs. As a result, there is little uncertainty in terms of the required technologies for product development. The major factor of successfully managing such NPD lies in the proficiency of identifying and satisfying customers' existing requirements. In the current research, cases from the fieldwork identified as Tried and Tested Incrementals are all successful innovations. This may be due to the low technical uncertainty of product development. According to the classification stated in Chapter Five, Tried and Tested Incrementals have the following attributes:

(1) low profile new products,

(2) low novelty in the marketplace,

(3) low uncertainty at the beginning of product development,

(4) no difficulty in manufacturing, and

(5) familiarity of the producer with such a product class.

Statistical results from previous chapters suggest a unique pattern of NPD information processing and knowledge accumulation for this type of product innovation. They are more concerned about market trends, customer preferences, development costs, and the capability of mass production, rather than technologies or product-related information such as are strongly highlighted by other types of NPD project. Among all cases, they are the only type of NPD project that show enthusiasm for formal and large scale consumer surveys for product innovation. For them, technology is not everything; the key consideration is, how to satisfy customers' needs in less time and at lower cost. They are also the only NPD type that welcomes early participation of marketing and manufacturing functions during product development. They tend to be more open-minded to these non-technological functions than other NPD types.

However, functional interactions between marketing and R&D are often restricted to corporate-level only. At team-level management, the multi-disciplinary teams that are common for developing Untried Incrementals are rarely found in the cases of Tried and Tested Incrementals. Corporate project control is mainly based on Project Committee Model where the committee provides an interface for functional integration. However, for team-level deployment, the pursuit of efficiency in product development is highly stressed. As the technologies employed by product development are not very complicated or sophisticated, it is possible to utilize the concept of "specialisation" from mass-manufacturing to accelerate development cycle time. The project teams are made up primarily of R&D people and manufacturing people. Horizontal communications and integration within R&D is also fewer. People often concentrate on their own specialities without too much interaction with others. The accumulation of NPD information and knowledge is based on documentation as well as keeping a few key people. It is less likely that these NPD will employ highly sophisticated information technologies such as networking or group computing for facilitating information processing.

10.5.2 Successful Case: SLTV

SLTV stands for Super Large Television, which are televisions with normal definition but equipped with super large screens (i.e., from 28" to 37" diagonally). They were first developed and produced by Chun Yun Corporation in 1991 for the Taiwan market. However, after their great success in the domestic market, they are now also available in some foreign countries, such as the USA.

The product idea for SLTV was a result of emerging needs for audiovisual presentations at public places, such as railway stations, airports, public squares, and KTV[12]. Government and advertising agencies have long been utilizing posters or outdoor billboards for announcing policies or advertisement. However, these traditional media can only present still images which are far too lifeless and therefore highly ineffective. There was increasing need for large scale facilities that can handle text, sound, video, and moving pictures. In particular, the Taiwanese stock market boom in the late 1990s has created a great demand for public presentation facilities which allow up-to-the-second stock prices at stock broking firms. SLTV provides an electronic solution for this market.

Established in 1984, Chun Yun is a relatively small company compared with other companies participating in the current study. Its average R&D expenditure to annual turnover was about 5%. New products introduced in the previous five years contributed about 85% of total sales. Twenty NPD projects were undertaken in the company in the previous five years; all of them actually reached the marketplace. However, only 13 of these new products were regarded as successful. Since the company is small, it cannot afford to pursue cost-leadership by mass-producing ordinary products. In the past years they have tried to pursue a product differentiation strategy through high-end scientific research. However, most of these efforts seem to be in vain. As the pursuit of technological leadership requires great investment in R&D and ends with little positive result for the company, Chun Yun has gradually turned to a niche strategy for its survival. To pursue a niche strategy, sensitivity to market trends is very important. The company should be able to detect the gap between demand (i.e., consumer needs) and supply (i.e., benefits offered by existing products) quickly and effectively. To do so, Chun Yun has successfully established a special approach for NPD management, i.e., "innovation via company-wide participation."

The concept of "innovation via company-wide participation" is a managerial design attempting to incorporate every effort from every employee in the company into the NPD process. For Chun Yun, such company-wide participation is really company-wide; from CEO down to workshop employees, the entire workforce is involved in product development. It regards all its employees as a sample of customers; through the 300 or so employees in the company, customers' needs can be easily understood. Workshop employees in effect play the key role in the whole NPD process. First of all, idea generation for new product development is a company-wide programme in which employees who provide new product concepts receive additional substantial monetary rewards. As a result, many new product ideas were initiated by workshop employees rather than R&D or Marketing people. Secondly, during the concept development stage, every employee is responsible for appraising and criticizing new product prototypes. For each design of prototype (which presents shapes, colours, and functionality), clay models or wooden mock-ups are circulated to all functional departments for a company-wide referendum. Results from such a referendum determine the subsequent direction of product development. Thirdly, all employees also participate in validating the final prototypes. A couple of sample products produced in pilot run are provided for all functional departments. All employees therefore have an opportunity to try out the new product and in the meantime provide feedback about the new product to the R&D department. Of course, additional monetary rewards are available for employees who provide this feedback.

Besides the above company-wide participation in the NPD process, corporate R&D management also shows a multi-discipline flavour. Based on the Project Committee Model, every functional department has a voice in every NPD project. Functional coupling is frequent. Especially in the early stages, there is rich communication between R&D and other functional departments in terms of the availability of components/materials, manufacturing process, and cost estimate. However, at project-level NPD management, team composition is simpler and mainly comprises R&D people. In effect at the time of the current research, only 15 engineers were working in the R&D department accounting for about 5% of the total workforce. These engineers are divided into several sub-functions such as electronic design, video signal, power supply, distortion engineering, system design, industrial standard, and industrial design. Each project is undertaken based on the Specification Model -- NPD projects are treated as products which are rolled through the mass-production line. Each sub-function acts as a workshop that takes several new product development projects at a time and hands over the development results to the next sub-function sequentially.

The development of SLTV is a typical case of NPD management in Chun Yun. All R&D work was implemented in-house, except the necessary software which was contracted-out to an external design house. Its project-level NPD management was based on the Specification Model in which there was in effect no "SLTV team". This project was rolling through all sub-functions in R&D. All employees had participated in screening product concepts, prototypes, and finally validating the quality of the final product. Technologies embedded in product design were basic; however, it created a new segment of the domestic market. By using the same technologies employed in normal-dimension televisions, SLTV does not provide better video quality in terms of picture definition and resolution. In effect, the overall impression of its picture quality is even worse as the creation of such a large screen image is based on a simple mapping technology that projects each pixel of the original picture onto a larger screen. However, as this product has never been presented as a high-end video system, customers are satisfied with its current quality performance and, therefore, it has been highly successful.

10.5.3 Successful Case: SDI Cartridge Stapler

Staplers are very common items of stationery for binding a small quantity of papers. As they are often very small, portable, and cheap, they are highly popular in everyone's everyday life. Their mechanic structure is simple. Most staplers are designed with a limited capacity for binding a certain number of papers. For example, to bind five pages of papers a small stapler is adequate; however, to bind 20 pages of paper, one needs to buy an additional larger capacity stapler for doing the job properly. Consequently, one needs to buy an even larger capacity stapler for binding 30 pages of paper and another one for 50 pages and so on. As a result, many people have been forced to be stapler-collectors, owning several at a time. This is an unsatisfactory situation for stapler users. The Cassette-Loading Stapler is a solution for dealing with such a capacity problem.

The SDI Cartridge Stapler was not the world's first stapler to provide cassette-loading capability; probably it was among the many "me-toos" in the world. The first cassette-loading stapler was developed by a Japanese company in the early 1990s. Unlike the traditional staplers which use a tray to store and convey staples, the new stapler uses disposable cartridges. Different dimensions of cartridge are provided for carrying different specifications of staples. As a result, this pioneer product provides a wide range of capacities for binding papers, i.e., up to 80 sheets thickness of 80-gramme paper. Users therefore can match staple size to document thickness, rather than replacing the stapler. SDI Cartridge Stapler was a "second but better" product that imitated the original Japanese design.

The original cassette-loading stapler provided by the Japanese has a drawback in terms of stapling quality. The supplied cartridge was produced in plastic in an attempt to reduce the additional cost of the accessory staples. As the material used for making staple cartridge is relatively soft, the mechanism for pushing staples and the punching path of the stapler should be highly precise so as to bump off staples smoothly without hurting the surface of the cartridge. However, the original Japanese design for such a stapler did not provide a good mechanism to prevent imprecise punching. Staple jam is common as a scratch on the cartridge surface easily distorts the accuracy of the whole system. By imitating the functionality of the original product concept, SDI developed a better mechanism that provides more precise stapling.

Established in 1954, SDI Corporation has been an expert at providing precise dies for mechanical industry. This company gradually diversified by producing other product categories such as IC lead frames, precise electronic parts, and office stationery -- based on the core competence accumulated from precise machinery. However, most of these product lines are merely the manufacturing of standard industrial components, without the need for product innovation. They are often highly manufacturing-oriented and the key issue in product management is proficiency in facilitating mass production. The only product category in the company that is more active in R&D is the office stationery product line. The Functional Model is used for managing corporate-level R&D. However, all NPD projects were initiated and led by the marketing function. The R&D department to some extent was treated as a less important and passive function, responsible for merely supporting the technical needs requested by the marketing function.

The R&D department in SDI is relatively small compared with other companies in the current study. The Specialisation Model is employed for project-level NPD management. There were 24 people assigned to R&D during the research period; among them, five people were industrial designers and the rest were engineers specializing in tooling design and manufacturing. Based on such a team composition, clearly the capability of mass production has been given the highest priority in product innovation. As a result, nearly all NPD that were undertaken in previous years were Tried and Tested Incrementals. Such product innovations require less R&D investment and produce better NPD success rates. However, they also have less impact on overall performance in terms of corporate growth. The average ratio of R&D expenditure to annual turnover is 1.5%. In the previous five years about 50 NPD projects were conducted by the company; all of them have actually been commercialized and regarded as successful. These new products contributed about 30% to the total sales.

Their experiences in precise machinery and proficiency in mass-production have provided a sufficient technological basis for the Cartridge Stapler project. As the product concept and functionality of this product were imitated from an existing successful product, there is little uncertainty in terms of both product technology and marketplace. The major challenge to this NPD was to find a new system design that could avoid violating patent protection of the original design and meanwhile provide better product usability. Supported by their strong capability in tooling design and manufacturing, the SDI R&D has successfully designed a new structure of the cartridge stapler that uses less material and can be more reliably mass-produced. They have successfully borrowed the product concept from the existing product, but, they did not imitate the original design and, therefore, covered the product from the dangers of patent piracy.

10.5.4 *What Can Be Learnt from These Stories?*

According to the above cases, Tried and Tested Incrementals tend to be market-led product innovations. They are products that intend to satisfy customers' current needs rather than future needs. As a result, the fit between the product concept and the customers' needs is important. More critically, the capability of high quality but low cost mass-production of the final product is the key to competing with existing competitive products. There is a high level of multi-disciplinary coupling. The marketing function particularly provides necessary insights into customer needs and market trends to suite product design, while the manufacturing function provides the helpful vision for facilitating the concept of "design for manufacturing". The participation of more people (e.g., workshop workers and customers) during the development process is useful to bridge the gap between product designer and users. Formal communication channels are often provided for corporate-level functional integration. However, at the team-level, the structural design is such as to reduce unnecessary communication so as to improve development efficiency and, therefore, shrink development cycle time.

§10.6 Managing Information for Effective Product Innovation

This chapter provides eleven stories describing how successful and unsuccessful NPD were managed. It is clear that the proficiency of contingent management of information and knowledge is the key to successful project implementation. For each type of NPD there are exclusive rules that should be followed by firms so as to better manage product innovation. For example, the isolation of a project team from the interference of other functional departments will greatly benefit Easy-to-Produce Radicals, because this provides the scientists/engineers with a better environment to concentrate on the invention/investigation of highly radical technologies. However, such a separation can obstruct the development of Untried Incrementals where multi-discipline information sharing and learning are far more critical.

The involvement of marketing in R&D is another example that highlights the need for a contingent approach to NPD management. While successful Tried and Tested Incrementals rely heavily on the marketing function to provide information to decide project direction and product design, successful Easy-to-Produce Radicals and Hard-to-Produce Radicals seem to avoid a market-led approach in product innovation. In effect, the Music FaxModem case suggests that an over-involvement of marketing function is harmful to radical innovations because of the risky application of immature technologies.

Even products that fall into the same category of radical innovations, or those that can be classified as incremental innovations, show their own specific needs for NPD information management. For radical innovations, Easy-to-Produce Radicals require a more isolated mode of information processing, where information is managed via machine-based networking focused on inward information concentration and gathering to a few key people; however, Hard-to-Produce Radicals tend to rely on human-based communication with a more open mind to encourage information sharing among all members. With regard to incremental innovations, Untried Incrementals tend to construct their highly rich communication networks at project-level, through informal inter-personal interactions, underneath the formal organisational structure; on the other hand, Tried and Tested Incrementals utilize more formal channels at corporate-level and, meanwhile, reduce horizontal communications at project-level to accelerate development efficiency.

Clearly, the proper control of information processing according to specific project situations/conditions is one of the major keys to effective product innovation. Fortunately, from empirical evidence this study has successfully identified contingent rules for this purpose. Case studies presented in this chapter further provide direct and qualitative insight into how successful firms implement these rules. These industrial stories display the validity of the quantitative findings in this study. Conclusions of these findings are provided in the next chapter.

Notes

1. PCMCIA is a widely accepted standard setup by the Personal Computer Memory Card International Association. It behaves in two ways: it can provide extra storage space (like a hard disk) and it can also be used to connect peripherals, such as modems or network cards. The cards look like thick credit cards. Because they are so small, the card readers which hold them are most commonly found in portable PCs.

2. The exchange rate between NT dollars and US dollars is around 26:1 in 1994. Therefore, NT$528 million are roughly equivalent to US$20.5 million.

3. ASIC stands for Application Specific Integrated Circuits, which are customized chip sets designed for specific electronic systems.

4. IRQs are the system interrupts for catching the attention of the computer. They are the hardware lines used to send service requests from peripherals to the CPU (Central Processing Unit) of a computer. For example, the IRQ 4 is exclusively for the first and the third communication ports (COM1 and COM2) with the Base I/O addresses of 03f8 and 03e8 respectively. DMA stands for the Direct Memory Address, which is the channel for peripherals to transfer data directly to and from system memory by bypassing the CPU.

5. A scanner with an automatic page feeding mechanism similar to that of the photocopy machines.

6. OCR stands for Optical Character Recognition. Such a mechanism converts scanned images of documents into editable text files.

7. BBS stands for Bulletin Board Systems which are electronic bulletin boards existing in many computer network systems. In such a system the host computer provides disk spaces as well as computing time for the home computer users to "up load" and "down load" softwares, files, messages, discussions, or even questionnaires, or advertisement materials through modem and telephone wires.

8. Pentiums are a new family of processor chips developed by Intel Corporation for the personal computers. They are the first 64-bit Intel chips that provide up to 120 MHz, the highest clock speed currently available in a personal computer. The heart of Pentium chip is a parallel 386-type processor engine with highly advanced circuitry miniaturisation, which provides the amazing horsepower to this processor. Meanwhile, Pentiums also provide backwards-compatibility to the existing 386/486 applications and therefore these softwares will still run on a Pentium-based computer.

9. Some computers are made by using a crippled version of the Pentium chip (i.e., the Pentium P24T), with a 32-bit external data path rather than the full 64-bit architecture the standard Pentium has. These computers are Pentium-ready but not "real" Pentium-based computers. They can be upgraded to a real Pentium machine by adding a Pentium Overdrive. However, they are not optimized to run under a Pentium processor.

10. An industrial-grade production colour scanner is one that can digitize more than 30 publication-quality scans in one 8-hour shift. A scanner for publication-quality prepress should be capable of at least 2,000 pixels per inch of resolution. See: Chrusciel, E. and D. Rogers (1993), 'What to Look For in a Color Scanner,' *Graphic Arts Monthly*, 65, 7, 76-78.

11. DCR, which stands for Dynamic Colour Rendition, was developed by Microtek for rendering the colour reproduction of scanning results. This professional colour calibration system sets the scanners to an industry-standard colour target. Scan an image, and its colour values are automatically compared with ideal values and adjusted if need be. The resultant colours of the scanned image closely match the original, and therefore require less time on final corrections.

12 As MTV stands for Music TV (television), KTV stands for Karaoke TV, a popular leisure activity initiated by the Japanese. The basic facility for such a leisure activity is a large scale television with audio/video systems. Customers sit in front of the screen and sing songs by following the music from the audio system and the lyrics and videos on the screen.

Chapter Eleven

Research Conclusions

11

As highlighted in the introductory chapter, there are two purposes for the current study: (1) to investigate the nature of NPD dynamics, so as to differentiate the underlying structure of NPD situations/conditions, (2) to examine whether the management of NPD information processing and knowledge accumulation are contingent upon such NPD situations/conditions. Empirical evidence in the study suggests that successful firms do tend to shape their NPD structure and information processing strategy to suit a particular type of product innovation. This chapter draws conclusions from these findings based on quantitative analyses and qualitative observations presented in previous chapters. While these conclusions are significant to confirm the value of the proposed contingent approach to NPD information/knowledge management, limitations of these findings are also discussed to better interpret the research results. Implications and applications of these findings are discussed. Suggestions for future research are also provided.

11 Research Conclusions

§11.1 Introduction

The initial motivation of the current study is to answer the question whether or not it is beneficial for firms to tailor their new product development strategies to accommodate different project situations and conditions. This question is important because it focuses on a key issue in both corporate strategic planning and NPD management. On one hand, to cope with different external and internal project situations, a contingent approach to NPD management may be necessary to reduce the risk of inappropriate product innovation management. On the other hand, a contingent managerial arrangement may consume more corporate resources and managerial efforts than a uniform approach, which, in turn, increases the risk of greater loss if the project fails. This is indeed a dilemma for NPD management. To solve this problem, this study investigated the nature of product innovation and its incumbent environmental dynamics.

Three enquiries form the basis of the current study. The first is whether the underlying dynamics of NPD management caused by internal and external contingent situations/conditions are analysable. If so, the development of a contingent framework for NPD management is therefore possible. The second enquiry concerns how far the contingent approach can be applied to commercial NPD practices. As the management of information processing and knowledge accumulation is one of the major issues in NPD, only these key activities are discussed in the current study. The third enquiry considers additional organisational deployment/arrangement that can be used to facilitate NPD information/knowledge management. A comprehensive literature review was conducted to find answers to the above enquiries; however, answers from previous studies were far from satisfactory. Five propositions and thirty research hypotheses were therefore developed in an attempt to provide better insight into the understanding of NPD management.

Evidence from the current study strongly supports the research propositions. Most hypotheses are also supported based on quantitative results. A summary of test results of these hypotheses is presented in Table 11.1. Research findings, implications, limitations, and suggestions for further research are discussed in the following sections.

§11.2 Research Conclusions

11.2.1 Dynamic But Analysable: NPD Contingencies

Finding 1: The underlying structure of NPD dynamics is analysable.

The current study implemented multivariate techniques to uncover the underlying structure of NPD dynamics. Twenty-five contingent variables were analysed and resulted in the following contingent factors:

Internal Contingent Situations:

(1) Superiority of Product Profile,

(2) Company Synergy,

(3) Difficulty in Manufacturing,

(4) Clearness about Project, and

(5) Uniqueness of Product.

External Contingent Situations:

(1) Market Size,

(2) Market Growth,

(3) Competitive Situation, and

(4) Product Life Cycle.

These factors are consistent with NPD determinant studies in which these factors were used to forecast *post hoc* NPD performance (e.g., Cooper, 1981, 1984b, 1985, 1992; Link, 1987). Furthermore, based on these contingent factors, NPD projects can be classified, each being represented by a different set of project situations/conditions.

Based on *Internal Contingent Factors*, four NPD types were identified:

Table 11.1 Empirical Examination of Research Hypotheses

	Research Hypotheses	*Empirical Evidences*
1.1	Management's perceived importance of a specific type of information required for successful NPD projects varies significantly with the type of new product project undertaken.	✔
1.2	Management's perceived importance of a specific type of information required for successful NPD projects varies significantly with the dynamics of its incumbent marketplace.	❖
1.3	For successful NPD, the actual efforts spent in acquiring a specific type of information vary significantly with the type of new product project undertaken.	✔
1.4	For successful NPD, the actual efforts spent in acquiring a specific type of information vary significantly with the dynamics of its incumbent marketplace.	❖
2.1	For successful NPD, the selection of information sources varies significantly with the type of new product project undertaken.	✔
2.2	For successful NPD, the selection of information sources varies significantly with the dynamics of its incumbent marketplace.	✘
2.3	For successful NPD, the key players in information acquisition vary significantly with the type of new product project undertaken.	✔
2.4	For successful NPD, the key players in information acquisition vary significantly with the dynamics of its incumbent marketplace.	❖
2.5	For successful NPD, the timing for information acquisition varies significantly with the type of new product project undertaken.	✔
2.6	For successful NPD, the timing for information acquisition varies significantly with the dynamics of its incumbent marketplace.	✔
3.1	For successful NPD, the extent of departmental coupling during product innovation varies significantly with the type of new product project undertaken.	✔
3.2	For successful NPD, the extent of departmental coupling during product innovation varies significantly with the dynamics of its incumbent marketplace.	✘
3.3	For successful NPD, the level of information redundancy during product innovation varies significantly with the type of new product project undertaken.	✔
3.4	For successful NPD, the level of information redundancy during product innovation varies significantly with the dynamics of its incumbent marketplace.	❖
3.5	For successful NPD, the nature of communication channels employed during product innovation varies significantly with the type of new product project undertaken	✔
3.6	For successful NPD, the nature of communication channels employed during product innovation varies significantly with the dynamics of its incumbent marketplace.	❖
4.1	For successful NPD, the managerial arrangements for facilitating information processing vary significantly with the type of new product project undertaken.	✔
4.2	For successful NPD, the managerial arrangements for facilitating information processing vary significantly with the dynamics of its incumbent marketplace.	✘
4.3	For successful NPD, the managerial arrangements for facilitating information assimilation vary significantly with the type of new product project undertaken.	✔
4.4	For successful NPD, the managerial arrangements for facilitating information assimilation vary significantly with the dynamics of its incumbent marketplace	✘
4.5	For successful NPD, the managerial arrangements for facilitating knowledge accumulation vary significantly with the type of new product project undertaken.	❖
4.6	For successful NPD, the managerial arrangements for facilitating knowledge accumulation vary significantly with the dynamics of its incumbent marketplace	❖
5.1	For successful NPD, firms tend not to tailor their NPD management models at corporate-level for every specific type of product innovation.	✔
5.2	For successful NPD, firms tend not to tailor their NPD management models at corporate-level in coping with the market dynamics of a specific project.	✔
5.3	For successful NPD, firms tend to tailor their NPD management models at project-level for every specific type of product innovation.	✔
5.4	For successful NPD, firms tend to tailor their NPD management models at project-level in coping with the market dynamics of a specific project.	❖
5.5	For successful NPD, the use of NPD process models for fostering product innovation varies significantly according to the type of new product project undertaken.	✔
5.6	For successful NPD, the use of NPD process models for fostering product innovation varies significantly according to the dynamics of its incumbent marketplace.	✘
5.7	For successful NPD, the project team composition varies significantly according to the type of new product project undertaken.	✔
5.8	For successful NPD, the project team composition varies significantly according to the dynamics of its incumbent marketplace.	✘

Empirical Results: ✔ = Accepted; ✘ = Rejected; ❖ = Partially Accepted

(1) Easy-to-Produce Radicals,

(2) Hard-to-Produce Radicals,

(3) Untried Incrementals, and

(4) Tried and Tested Incrementals.

Based on *External Contingent Factors*, three groups of NPD project were obtained:

(1) NPD under Turbulent Market Situations,

(2) NPD under Declining Market Situations, and

(3) NPD under Stable Market Situations.

Finding 2: Firms with different characteristics (e.g., scale, established years) and different strategic foci (e.g., R&D input, risk taking, pricing strategy) tend to be proficient in different types of new product development.

NPD Types	*Company Characteristics*	*Company Strategic Foci*
Easy-to-Produce Radicals	younger and smaller	heavy R&D input, high pricing policy
Hard-to-Produce Radicals	larger and better established	risk taking, small scale production
Untried Incrementals	better established	low R&D input, mass-production
Tried and Tested Incrementals	better established	low R&D input, risk taking

Source: Section 5.4. Table 5.11 and Table 5.12.

11.2.2 Managing Information for Effective Product Innovation

Finding 3: Classifications of NPD into only radical/incremental or routine/ nonroutine groups are misleading, because such classifications generate significant within-group variances.

Classifications of NPD into only radical/incremental or routine/nonroutine groups do not reflect the nature of NPD management. Empirical evidence suggests that there are significant differences between Easy-to-Produce Radicals and Hard-to-Produce Radicals as well as between Untried Incrementals and Tried and Tested Incrementals in terms of their patterns of NPD information processing.

Finding 4: On average, different types of information tend to have different impact upon the management of product innovation.

The top five most important types of information for product innovation are:

(1) Product-related Information,

(2) Technology/Science-related Information,

(3) Goal/Strategy-related Information,

(4) Market-related Information, and

(5) Supplier/Component-related Information.

Finding 5: Information requirements of successful NPD projects vary significantly according to the type of new product project undertaken and the market where it plans to sell.

NPD Types	*Major Information Requirements*
Easy-to-Produce Radicals	goal/strategy, regulation/law/industrial standard, product, technology
Hard-to-Produce Radicals	market, regulation/law/industrial standard, supplier, product, technology
Untried Incrementals	regulation/law/industrial standard, supplier, product, technology
Tried and Tested Incrementals	supplier, customer, cost/price, manufacturing
Environmental Situation	*Major Information Requirements*
Turbulent Market	market, supplier/component, cost/price, manufacturing
Declining Market	competition
Stable Market	technology/science

Source: Section 6.2. Tables 6.1 to 6.6.

Finding 6: The selection of NPD information sources is contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

NPD Types	Rich Sources	Unbounded Sources	Primary Sources	Formal Sources
Easy-to-Produce Radicals	✘	❖	✘	✔
Hard-to-Produce Radicals	✔	❖	❖	❖
Untried Incrementals	✔	✔	✘	✔
Tried and Tested Incrementals	❖	✘	✔	✘
Environmental Situation	Rich Sources	Unbounded Sources	Primary Sources	Formal Sources
Turbulent Market	✔	❖	❖	❖
Declining Market	❖	❖	❖	❖
Stable Market	✘	❖	❖	❖

Source: Section 6.3. Tables 6.7 to 6.12. (Please refer to the original tables since these source selection behaviour vary significantly according to different information types.)
✔ more; ❖ moderate, ✘ fewer

Finding 7: R&D is the key player for most NPD types. However, the use of key information acquisitors is contingent upon the type of new product project undertaken.

NPD Types	CEO	R&D	Marketing	Committee
Easy-to-Produce Radicals	✔	❖	✘	✘
Hard-to-Produce Radicals	✘	✔	✘	✔
Untried Incrementals	❖	✔	✘	✔
Tried and Tested Incrementals	✘	✘	✔	✘

Source: Section 6.4. Table 6.14. ✔ more; ❖ moderate, ✘ fewer

Finding 8: The timing for acquiring NPD information is contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

NPD Types	*Earlier Acquisition*	*Later Acquisition*
Easy-to-Produce Radicals	-	supplier, cost/price, production
Hard-to-Produce Radicals	cost/price	manufacturing
Untried Incrementals	supplier, competitor	cost/price, manufacturing
Tried and Tested Incrementals	supplier, cost/price, manufacturing	competitor
Environmental Situation	***Earlier Acquisition***	***Later Acquisition***
Turbulent Market	-	goal, competition, customer
Declining Market	goal/strategy, customer	-
Stable Market	goal/strategy, competitor	-

Source: Section 6.5. Tables 6.15 and 6.16.

Finding 9: The mode of information transmission for successful NPD is contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

NPD Types	Extent of Departmental Coupling	Extent of Information Redundancy
Easy-to-Produce Radicals	✘	✘
Hard-to-Produce Radicals	❖	✔
Untried Incrementals	❖	❖
Tried and Tested Incrementals	✔	✔
Environmental Situation	Extent of Departmental Coupling	Extent of Information Redundancy
Turbulent Market	❖	✔
Declining Market	❖	❖
Stable Market	❖	✘

Source: Sections 7.2 and 7.3. Tables 7.1 to 7.5. (Please refer to the original tables since these information transmission behaviour vary significantly according to information type.)

✔ high; ❖ moderate, ✘ low

Finding 10: The selection of NPD communication channels is contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

NPD Types	Indirect Channels	Informal Channels
Easy-to-Produce Radicals	✘	✔
Hard-to-Produce Radicals	✔	✘
Untried Incrementals	❖	❖
Tried and Tested Incrementals	❖	✘
Environmental Situation	Indirect Channels	Informal Channels
Turbulent Market	❖	✘
Declining Market	❖	✔
Stable Market	❖	❖

Source: Sections 7.4. Tables 7.6 to 7.9. (Please refer to the original tables since these information transmission behaviour vary significantly according to information type.)

✔ more; ❖ moderate, ✘ fewer

11.2.3 Organisational Deployment Can Help to Facilitate NPD Information/Knowledge Management

Finding 11: The contingent use of specific managerial arrangements can help to facilitate NPD information processing.

NPD Types	*Useful Information Facilitators*
Easy-to-Produce Radicals	machine-based information acquisition, inward information concentration, computer networking, global information sharing, on-line groupware, keeping original team members, information sharing seminar, chief scientist as NPD supervisor
Hard-to-Produce Radicals	human-based information acquisition, outward information sharing, project monitor committee, multi-discipline stage review, computer networking, information sharing seminar, global information sharing, chief scientist as NPD supervisor
Untried Incrementals	multi-discipline happy club, project monitor committee, keeping original team members, global information sharing
Tried and Tested Incrementals	project monitor committee, global information sharing, computer networking

Source: Section 8.2. Tables 8.1 and 8.2.

(For definition of each information facilitator please refer to Section 8.2)

Finding 12: The contingent use of specific managerial arrangements can help to facilitate NPD information assimilation.

NPD Types	*Useful Information Digesters*
Easy-to-Produce Radicals	learning via a few key people, learning via documentation, learning via electronic machines, learning via organisational procedure
Hard-to-Produce Radicals	learning via a few key people, learning via all team members, learning via organisational procedures, learning via documentation
Untried Incrementals	learning via documentation
Tried and Tested Incrementals	learning via a few key people, learning via documentation

Source: Section 8.3. Table 8.3. (For definition of each information digester please refer to Section 8.3)

Finding 13: The contingent use of specific team-level organisational designs can help to facilitate product innovation.

NPD Types	*Useful Team Management Models*
Easy-to-Produce Radicals	Network Model, Virtual Team Model, Technology Supported Model, Matrix Model
Hard-to-Produce Radicals	Multi-discipline Model, Super-charged Designer Model, Matrix Model
Untried Incrementals	Network Model, Super-charged Designer Model, Twin Star Model
Tried and Tested Incrementals	Specialisation Model, Super-charged Designer Model

Source: Section 9.3. Table 9.4. (For definition of each team management model please refer to Section 9.3)

Finding 14: The contingent use of specific NPD process models can help to facilitate product innovation.

NPD Types	*Useful NPD Process Models*
Easy-to-Produce Radicals	Task-dominant Model, Process-dominant Model
Hard-to-Produce Radicals	Stage-dominant Model, Process-dominant Model
Untried Incrementals	Stage-dominant Model
Tried and Tested Incrementals	Process-dominant Model

Source: Section 9.4. Table 9.7. (For definition of each NPD process model please refer to Section 9.4)

Finding 15: The contingent design of team-level organisational deployment can help to facilitate product innovation.

NPD Types	Team Size	Member Background	Team Leadership	Team Composition
Easy-to-Produce Radicals	S	R&D		N
Hard-to-Produce Radicals	L	R&D	N	N
Untried Incrementals	S	R&D, MKT		
Tried and Tested Incrementals	S	R&D, MKT, MFG	C	C

Source: Section 9.5. Table 9.8.

S = smaller, L = larger, C = more likely to be changed during NPD, N = less likely to be changed during NPD; MKT = Marketing, MFG = Manufacturing

Finding 16: The extent to which a firm should shape itself to suit a particular NPD is at project-level, rather than at corporate-level.

According to the quantitative results presented in Chapter 9, internal as well as external contingent factors show little effect upon the use of NPD management models at corporate-level, while the effects upon model usage at project-level are significant. This suggests that the key point of NPD contingent management is at project-level; there is lesser need for corporate-level organisational re-engineering for particular product innovation.

Finding 17: Overall, the effects of internal contingent factors upon successful new product development are significant, while the effects from external contingent factors are relatively weak.

This suggests that the major variances of factors that explain final project outcomes are controllable (because these variances are mostly from inside the firm itself). Firms can therefore concentrate their efforts on dealing with internal contingent factors rather than external ones, and such a contingent approach to NPD management can effectively improve the final results of product innovation.

§11.3 Research Contributions to NPD Management Theory

11.3.1 The Hidden Structure of NPD Contingencies

Previous studies into new product development often ignored or over-simplified the underlying structure of NPD and its dynamics. Many researches regarded NPD as a closed system without considering possible interferences caused by incumbent internal and external environment (e.g., Bonnet, 1986; Gupta and Wilemon, 1988; Peters, 1990; Clark and Fujumoto, 1991ab; Nonaka, 1990, 1991; Workman, 1993). Even though a few researchers did incorporate such moderator variables into their research models, their assumptions about the nature of NPD tended to be simplistic (e.g., Hauptman, 1986; Shrivastava and Souder, 1987; Fleischer and Liker, 1992; Keller, 1994), and they by no means represented the nature of real-world NPD practices. Other scholars, however, have challenged such a contingency concept, presenting empirical findings based on over-simplified classifications, that showed that NPD contingencies had no impact upon NPD management (e.g., Hise et al., 1990).

The current study has successfully highlighted the hidden structure of NPD contingencies. The process (i.e., research design) used to uncover such a hidden structure was validated by using the Kaiser-Meyer-Olkin Measure of Sampling Adequacy and the Bartlett Test of Sphericity. Cronbach Alpha Tests confirmed that the internal consistency of the structure was solid. Cluster Analysis and Discriminant Analysis further examined the applicability of the structure in classifying real-world NPD cases. The results were promising because the final groupings of NPD cases were significant, and the prediction of NPD behaviour based on such groupings was sound. This provides a basic tool for future studies, in which other NPD activities can be much more clearly observed by controlling these NPD contingent factors.

11.3.2 A More Detailed Anatomy of NPD Information/Knowledge Management

Two major limitations restricted the applicability of previous NPD researches, both caused by the research approach employed. First, many empirical researchers into product innovation based on quantitative methods and large sample size were well established in both their predictive ability and cross-population interpretation (e.g., Cooper, 1979; Cooper and Kleinschmidt, 1987abc; Song and Parry, 1992, 1993). However, due to the limitation of their research methods (e.g., mail survey), it was difficult for these studies to provide direct and in-depth observations into industrial practices. Moreover, as their research variables were pre-defined and the means to acquire research data were indirect, it was also difficult for them to capture the true nature of the research domain. Secondly, several qualitative case studies did provide in-depth observations of NPD practices (e.g., Nonaka, 1990, 1991; Bolton, 1993; Workman, 1993). However, these studies were constrained by the small number of non-representative observations; their research findings cannot be generalized to any population.

Only a few major studies such as the SAPPHO Study (Rothwell, 1972; Rothwell et al., 1974), the Stanford Project (Maidique and Zirger, 1984, 1985; Zirger and Maidique, 1990), Souder (1987, 1988), and Clark and Fujimoto (1991ab) that incorporated both qualitative and quantitative research approaches have significantly contributed to the building of NPD theoretical foundations. The current study follows the guidelines of these major studies which blended both research approaches into a single research design. All research data were acquired from in-depth interviews, which provided an opportunity for the researcher to observe directly real-world NPD information processing and knowledge accumulation. Moreover, both quantitative and qualitative instruments were used. Thus, the anatomy of industrial NPD practices in the current study is more complete and detailed, and is not constrained by the researcher's initial understanding of the research domain. Furthermore, the use of a representative sampling design with a relatively large sample size validates findings from this study to be generalized to a larger population (i.e., the sampling frame). The current study contributes to the main body of NPD theory a more in-depth perspective of the whole NPD information processing and knowledge management.

11.3.3 Contingent Management of Product Innovation

The current study confirms the assertion by previous researches that contingent factors impact upon the industrial practices of product innovation (e.g., Holland et al., 1976; Jermakowicz, 1978; Tushman, 1979; Allen, 1986; Hauptman, 1986; Shrivastava and Souder, 1987; Fleischer and Liker, 1992; Keller, 1994). Empirical evidence strongly supports the notion that internal contingent factors are significant. However, confirmation that external factors have effect is somewhat weak.

More important, all analyses in this study are based on classifications of NPD situations/conditions that are empirically identified from fieldwork; this further extends the frontier of conventional NPD contingency studies. Previous academic work into NPD contingency management was mainly based on hypothesized contingency variables, such as radical/incremental innovations (Jermakowicz, 1978; Thurmond and Kunak, 1988; Brown and Karagozoglu, 1989) or routine/nonroutine tasks (Hauptman, 1986; Fleischer and Liker, 1992; Keller, 1994); these classifications of NPD type are too broad and fail to reveal the true nature of NPD. The current study classifies NPD based on both internal and external project situations/conditions. For these project situations/conditions, four NPD types and three NPD market situations are identified. This renders a much more accurate picture of the reality of NPD management.

§11.4 Recommendations for Management Practices

The current study provides a comprehensive contingent framework for NPD information/knowledge management at project-level. It is hoped that firms can utilize the concepts and empirical results from the field study at both corporate-level and project-level. Insights drawn from this study also benefit system analysts seeking to develop information systems for product innovation. The following sub-sections list the implications for, and applications of the research findings to, new product management.

11.4.1 Implications for Firms

(1) To cope with different NPD situations/conditions, a pre-defined contingent framework for project-level organisational deployment is highly critical. However, corporate-level contingent frameworks are not necessary as they require too much resource input and produce too little effect.

(2) The structure of NPD dynamics uncovered by the current study may be

used as a basis for classifying such contingency frameworks. For example, for each NPD type, managerial arrangements, as well as organisational deployment for NPD information processing, can be prepared as guidelines for project planning and the actual implementation of product innovation.

(3) The major impacts of contingent factors upon a NPD project come from the project itself rather than from its incumbent external environment. This means that most variances contributing to final project outcomes are controllable. An early understanding of NPD situations/conditions can help management choose an appropriate NPD management strategy and therefore increase the likelihood of a successful outcome.

(4) Firms with certain characteristics may be more fit to pursue specific types of new product development. For example, young and small firms with high R&D input may be especially competent at developing Easy-to-Produce Radicals.

(5) Not all information types are equally important to every product innovation. Therefore, a contingent framework for NPD information processing based on different task types will be very helpful in improving the cost-effectiveness of a project.

(6) The necessity to involve other functional departments/individuals such as top management, marketing, and manufacturing in product innovation depends upon the type of NPD project undertaken. Not all functional departments need be involved in every type of NPD project.

(7) People, either key individuals in the projects or general R&D members, are the most important asset in product innovation. They play the vital role in preserving experiences and knowledge, as well as providing valuable lessons from failures, no documentation or computer technology can totally replace them.

11.4.2 Implications for Project Leaders

(1) The construction of a NPD task force should be contingent upon the specific requirements of the project. Different NPD types require different characteristics of team composition.

(2) Different information sources, communication channels, and information transmission patterns have different impact upon different types of NPD. Project leaders should understand the advantages and limitations of different sources/channels with respect to different NPD types.

(3) The timing for acquiring a specific type of NPD information is contingent upon the type of new product project undertaken and the dynamics of its incumbent marketplace.

(4) For Hard-to-Produce Radicals, involving more team members in information processing is important to successful project implementation. Project leaders should be able to create an atmosphere in which all project members are treated equally in sharing NPD information.

(5) For Easy-to-Produce Radicals, investment in computer networking can bring great benefits in NPD information processing and knowledge accumulation.

(6) Team leadership and team composition need not necessarily remain unchanged. For certain types of NPD, such changes during product development may produce even better project results.

11.4.3 Implications for Information System Developers

(1) NPD practices are analysable, which means that the development of information systems for product innovation is feasible.

(2) The quantitative instrument developed by the current study has been sufficiently validated, and it can be incorporated into such NPD information systems as a tool for differentiating NPD types as well as identifying external NPD situations/conditions.

(3) As different types of NPD present different patterns of information processing, a NPD information system should be able to deal with contingent situations associated with different NPD projects.

(4) For NPD knowledge management, humans can never be replaced by machines. An alternative is to use a machine as an assistant to a human for memorizing (i.e., recording) documentable historical events, figures, and drawings. Inference mechanisms may be incorporated into such systems for more efficient information retrieval and extraction.

§11.5 Limitations of these Research Findings

The results of this study are based on cross-sectional observations with limited samples from Taiwanese firms, and generalisations about other populations would be premature. These empirical results are valid only for certain economic systems and for a particular time – such as a highly energetic society with a very good quality education system and strong government support for industrial R&D.

Furthermore, quantitative analyses in the study were based only on successful cases because the sample size of failed cases was too small to generate any valid statistical comparisons. However, such a low failure rate of product innovations reflects the nature of the sampling frame and was supported by several previous local surveys (see the methodology chapter). The current study does not intend to assert that a thorough compliance with its recommendations can prevent NPD failure; rather, this study believes that these guidelines can help to give a better chance of NPD success. Nevertheless, a few case studies of failed NPD stories presented in Chapter 10 do show that NPD can fail when managerial guidelines generated from these successful industrial experiences are ignored.

The constraint imposed by sample size also forces the current study to analyse firm behaviour without considering the possible interactions between external and internal contingent factors. For each aspect of information processing, these two dimensions of factors are examined separately. Although internal factors show great impact on project-level NPD information processing, bias may exist because the relationships between internal factors and firm behaviour are moderated by external factors. Therefore, the use of findings in this study should be cautious.

Another limitation of the current study results from the employment of a *post hoc* research design. Informants were requested to recall NPD details that occurred during the previous five years. Due to the limitation of human memory it is possible that project information provided by the informants was distorted through time. However, this is a limitation shared by all non-longitudinal studies.

Finally, there is always a probability of difficulties caused by the measurement of certain concepts; however, the objectivity, validity, reliability, and practicality of the instrument design were all carefully examined and were revealed as unbiased (see Chapters Four). Any problem with measurement will not affect the current empirical results.

§11.6 Recommendations for Further Research

Although the current study has clearly portrayed the contingent management of NPD information processing and knowledge accumulation, the major drawback of these findings is the use of a *post hoc* cross-sectional research design. Historical events of each project were not directly observed and recorded in accordance with the contingent strategic movements of the firm. This largely weakens the validity of the data sets and reduces the capability of the current study to provide a truly complete and accurate picture of NPD reality. Surely, this is one of the common defects shared by most previous empirical NPD studies because of the limitation of available resources. However, theoretically, a large scale longitudinal study of the current research framework may be very useful for providing better insights into NPD information management. Techniques of Network Analysis may be employed to fulfil such a research design.

Insights drawn from the current research findings could also become a starting point for future research investigations. First, the underlying structure of NPD dynamics uncovered by the current study is based on observations of Taiwanese industrial experiences. As the nature of Taiwan's national R&D system is distinct from other economic systems (see Chapter Four), the underlying structure of NPD dynamics in other areas may present a totally different picture. It would be interesting to know whether there are certain common factors underlying general NPD practices. Therefore, a cross-population investigation of this issue could produce fruitful insights into our understanding of NPD management.

Secondly, findings from this study strongly suggest that a contingency approach is necessary for managing NPD information processing, knowledge accumulation, and project structure design. Further researches may extend this contingency view of NPD by investigating other aspects of NPD management, such as human resource management, product launch strategy, and product development process.

Thirdly, the findings concerning the contingent management of information assimilation (i.e., knowledge creation) and knowledge accumulation strongly support the continuous investigation of applications of organisational learning theory to the product innovation field. Organisational learning is a relatively new concept to product innovation theory. A complete theoretical development in this domain should incorporate information processing, information assimilation, and knowledge accumulation as applied to NPD. The current study provides initial findings on these issues at project level and suggests that further research into NPD organisational learning would be highly beneficial.

Finally, empirical results from the current study suggest that it would be difficult to replace

NPD knowledge management by machines, based on currently available technologies, although Easy-to-Produce Radicals did show a tendency to use computer-based techniques to handle information as well as knowledge. Researchers may find it interesting to investigate the interactions between humans, environmental dynamics, and the machine. It is possible to construct from the findings of such researches a learning machine which can help to facilitate future product innovations.

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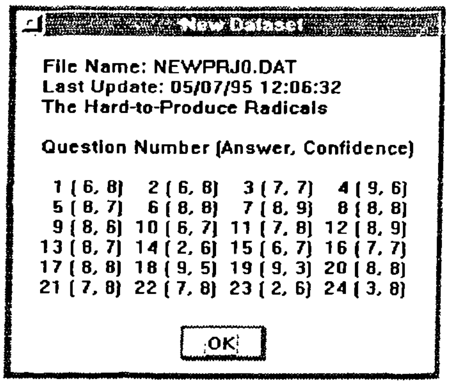
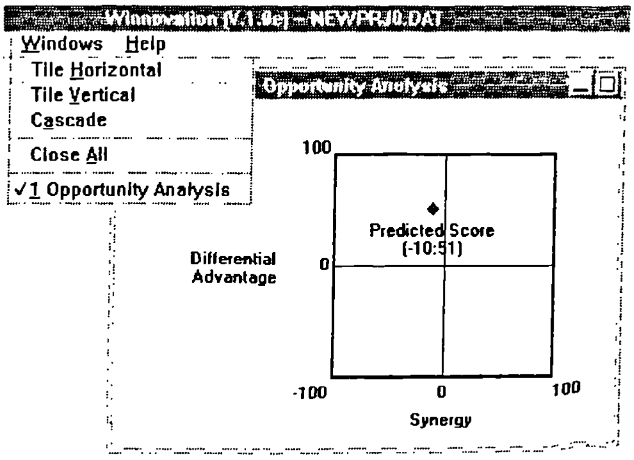
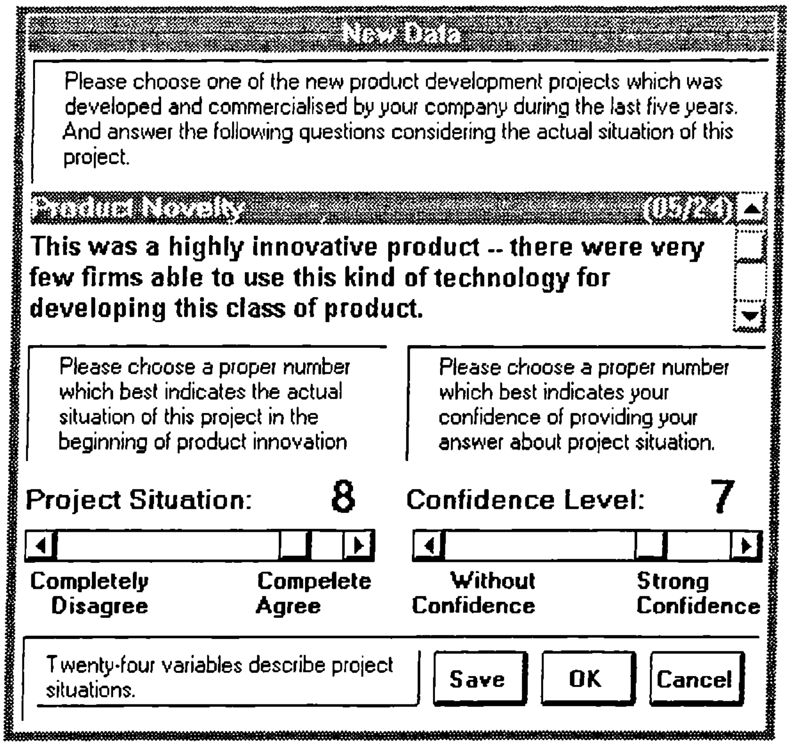
APPENDICES

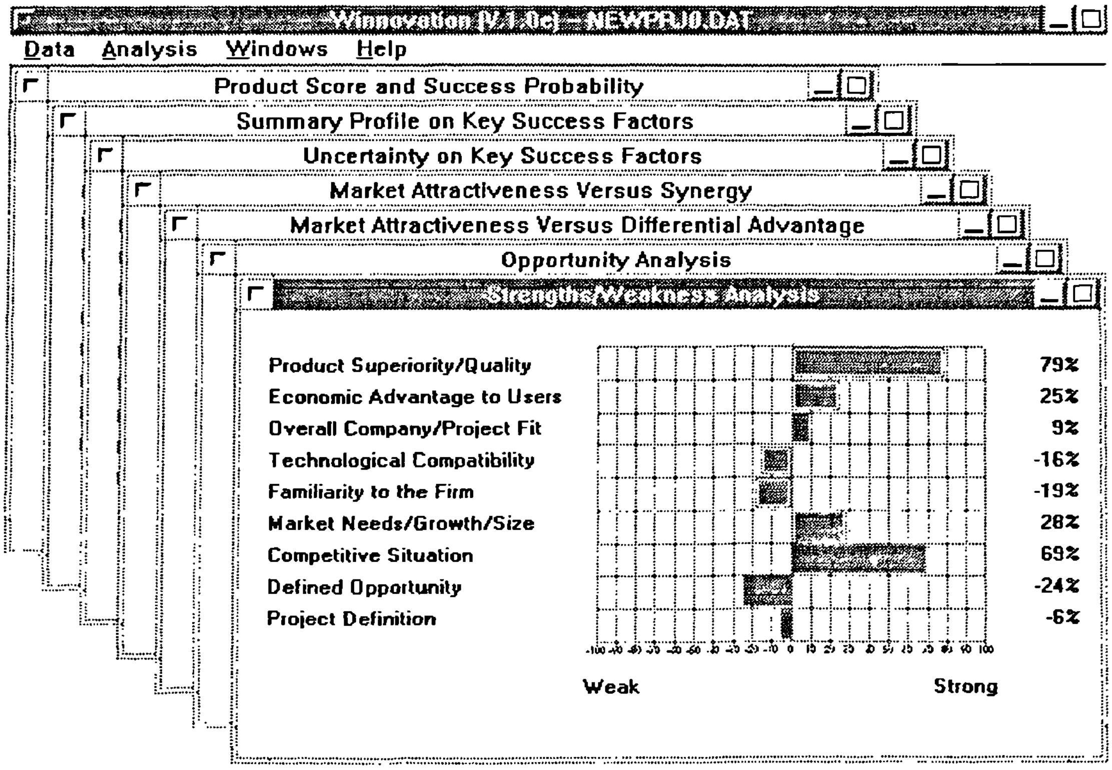
Appendix I The Software Incentive for Fieldwork: Winnovation 1.0e

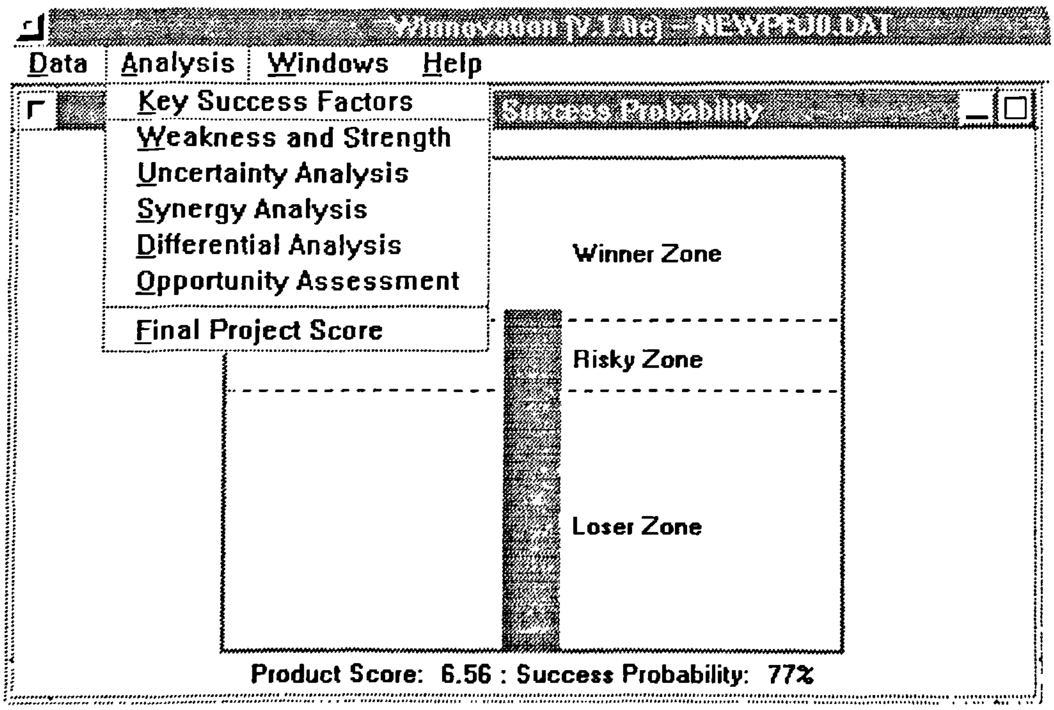
Winnovation is a project screening system based on the quantitative models developed by the Determinants School Studies (especially Cooper, 1979, 1981, 1982, 1992; Zirger and Maidique, 1990; Calantone et al., 1993; Song and Parry, 1994). Twenty four variables that describe the nature of new product development form the basis of this programme (see Quantitative Questionnaire, Part Two - F). These variables include the project familiarity to the firm (five measures), project novelty (three measures), project complexity (three measures), organisational commitment to the project (two measures), project initiation (one measure), project analysability (three measures), product positioning (three measures), and market situation (five measures). By using a 9-point semantic scale, the users are requested to provide answers for these variables as well as to state their confidence about the answers. The system is therefore able to calculate the score of each performance predictor and compares the results with the empirical conclusions from these previous researches. The following are several screen print-outs of this programme.








Winnovation [V.1.0c] – NEWPRJ0.DAT
Data Analysis Windows Help
Product Score and Success Probability
Summary Profile on Key Success Factors
Uncertainty on Key Success Factors
Market Attractiveness Versus Synergy
Market Attractiveness Versus Differential Advantage
Opportunity Analysis
Strengths/Weakness Analysis
Product Superiority/Quality 79%
Economic Advantage to Users 25%
Overall Company/Project Fit 9%
Technological Compatibility -16%
Familiarity to the Firm -19%
Market Needs/Growth/Size 28%
Competitive Situation 69%
Defined Opportunity -24%
Project Definition -6%
Weak
Strong


Winnovation [V.1.0c] – NEWPRJ0.DAT
Data Analysis Windows Help
Key Success Factors
Weakness and Strength
Uncertainty Analysis
Synergy Analysis
Differential Analysis
Opportunity Assessment
Final Project Score
Success Probability
Winner Zone
Risky Zone
Loser Zone
Product Score: 6.56 : Success Probability: 77%

Appendix II Correspondence for Exploratory Study

Attn. Mr. Peter Chen
Sampotek (UK) Limited
Unit 4, Millfield House
The Croxley Centre
Woodshots Meadow, Watford
Herts WD1 8XD

WARWICK
BUSINESS SCHOOL

陳先生您好：

小弟來自台灣，目前是 Warwick 大學商研所博士班研究生，因為研究上的需要，冒昧想請您撥冗接受一次訪談。素未謀面，唐突失禮之處，請您多多包涵！

我所研究的題目是：「新產品研發過程中，產品類別，資訊需求，與資訊傳遞模式之實證研究」(How Corporate Information Requirements/ Transmission Patterns Vary According to New Product Type: An Empirical Study)。研究方法係採用「深入訪談」(In-depth Interview)方式進行，研究對象中有一部份將是台灣的高科技廠商。這篇論文的研究草案(work-in-progress)很榮幸地已被第22屆「歐洲行銷年會」(EMAC Annual Conference)接受，理論模型部分，將於今年五月份在該年會中發表。現階段因已完成理論模型的建立，在實際回台灣進行大規模訪談之前，極需借重您在業界多年的實務經驗，來驗證這個理論模型的可行性，並請您對我的研究工具(訪談問卷)提供寶貴的批評與建議。

訪談時間預計兩小時，基本上將依照小弟事先擬就的「訪談問卷」內容向您請教。問卷內容主要是請您回想一或二件過去您曾接觸過的新產品開發專案(無論是成功或是失敗的例子均可)，並請教您在這個專案開發各階段中，貴公司蒐集和運用專案所需各類型資訊(例如：技術資訊、零組件資訊、消費者偏好、市場資訊....等)的情形。在訪談中將僅向您請教大致上資訊應用的情形，而不會涉及實際資訊內容與任何技術上的細節。

小弟十分需要您相助一臂之力，請您無論如何抽出一點點時間幫助我完成這個研究，在此謹先致上萬分的謝意。近日內小弟將另行致電和您聯絡，以確定您方便接受訪問的時間。非常謝謝您！

耑此敬頌

時祺

弟

敬上
1993年3月25日

PS. 我的聯絡地址和電話如下：
Mr. Ting-Jui Chou
PhD student in S.I.B.S.
University of Warwick
Coventry CV4 7AL
(TEL)0926-50508, (FAX)0203-523719

Appendix III Correspondence for Fieldwork

WARWICK
BUSINESS SCHOOL

您好：

臺灣製造業近年來的經營環境頗有江河日下的趨勢。一方面外有東南亞、大陸等國家或地區挾廉價勞力的優勢在國際市場上節節進逼，另一方面，國內勞工短缺、工資昂貴、環保抗爭事件時有所聞，在在不斷提高國內廠商的生產成本，降低台灣產品在國際上的競爭地位。身處這樣內外交迫的環境，台灣製造業的最佳策略顯然不是坐以待斃，而是設法有效利用島內爲數眾多的高級人力資源、充裕的資金、以及企業家本身靈活的市場洞察力，做好產品策略規劃，提升產品商品化能力，並利用新產品的高附加價值來開創眞正的競爭優勢。

事實上，新產品研發不一定要「高科技」才能「研發」。如何能更充分地掌握科技與市場趨勢、如何能更有效地整合行銷、研發、與製造資訊、如何能細水長流地累積研發知識與經驗，進而在既有基礎上創建更美好的未來，這些可能更是値得我們深思探討的問題。對於這些問題，小弟曾十分深入地蒐集並研究歐美科技先進國家在新產品研發方面的理論和作法，並發展出一些工具、架構，供進一步分析之用。爲期這些理論能在國內有效應用，除了國外廠商的實證數據外，也需要國內廠商熱情協助，提供實務上新產品研發的作法與經驗，才能據以驗證這些理論在台灣本土環境下實際應用的可行性。

由小弟手邊的資料顯示，貴公司是台灣少數眞正投入研發工作的廠商之一。您們的經驗對這項研究工作可說十分寶貴，因此非常希望能有此榮幸親至貴公司拜訪，和貴公司的研發人員更深入地切磋請益。訪問時間約需一小時，訪問對象以研發單位主管或專案負責人爲主，基本上想請教貴公司在進行不同類型新產品研發時的實際作法。訪問內容純係管理方面的討論，絕不涉及任何技術細節與公司內部機密。整個訪問過程將十分自由而不拘型式。受訪人員只要就個人所接觸的研發經驗儘情暢談即可，小弟自會將貴公司的寶貴經驗融入事先設計好的理論架構之中。當然，如果貴公司對本人的理論架構感興趣，小弟亦將不揣鄙陋和各位前輩共同討論。這個架構目前已分別獲選在歐洲兩個頗具規模的學術會議中（ＥＭＡＣ與ＭＥＧ）發表過，基本上應已粗具學術價値，或有値得貴公司參考之處。

此外，在訪問之際小弟亦將奉上一小小獻禮：「新產品研發專案評選系統」供貴公司參考試用。這套系統係小弟依據國外實證數據資料與統計模式自行研展而成，採功能表選單與滑鼠驅動方式可分別在ＤＯＳ或中文視窗環境下操作，希望對貴公司的研發業務能略盡棉薄。

素未謀面，冒昧請您安排訪談，唐突失禮之處請多包涵，在此謹先致上萬分歉意與謝意。隨函並附上回條，請您指定訪問時間、地點、與接受訪問對象，填好回條後麻煩您以傳眞傳回或信件寄回。非常謝謝您！

耑此敬頌
時祺

晚

敬上
1993年11月26日

THE UNIVERSITY OF WARWICK COVENTRY CV4 7AL UNITED KINGDOM
TELEPHONE +44 (0)1203 524306
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華瑞克大學(The University of Warwick)簡介：

創校於一九六〇年代中期，華瑞克大學是英國１２２所大學中設備最爲現代化的大學之一。位於英格蘭中部地區，校園佔地五百公頃，是英國大學中的後起之秀。雖然本校在台灣的知名度仍然欠高，但在歐洲地區則頗負盛名（例如兩年前在德國舉行的歐洲大學校長會議中本校就曾獲選歐洲最佳大學之一）。英國首相梅傑曾多次在公開場合要求全英國的大學要多多向華瑞克大學看齊（尤其指名牛津和劍橋二校），因爲這些把自己關在象牙塔內的學校天天向政府要經費，治校卻不見績效；反觀本校，算是英國最富有的大學之一，經費中有８０％卻是來自與企業界合作的研究計劃，根本不用向英國政府叫窮（見英國經濟學人雜誌）。依據１９９２年１２月英國教育部「大學撥款委員會」公佈的排名資料顯示，華瑞克大學的全校整體排名在英國大學中名列第八，如果排除獨立學院不計，只計算綜合大學排名，則名列第四，僅次於劍橋、牛津、和倫敦大學之後。至於商學研究所排名，則不論根據「大學撥款委員會」的排名資料，或是倫敦泰晤士報１９９２年１０月公佈的調查報告，華瑞克商學院(Warwick Business School)都名列第一（只有新興大學才走得出象牙塔，不怕銅臭味！）

個人簡歷：

姓　　名：　周庭銳

學　　歷：　台灣工業技術學院工業管理技術系畢業
中原大學企業管理研究所碩士（專攻領域：新產品行銷管理）
英國華瑞克大學商學研究所博士班研究生（專攻領域：新產品研究發展管理）

主要經歷：　中原大學企業管理學系兼任講師（授課：資訊管理）
羽田機械公司總管理處專員、技術研究中心專員、駐英國研發中心專員

聯絡地址：　台中縣大甲鎮雁門路１９９之２號
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關於贈品：「新產品研發專案評選系統」

目前歐美日等國家的研發能力強過我國，是因爲他們有很好的研發管理經驗，尤其每年許多關於研發策略研擬、專案管理技術的實證研究結果眞正在企業界落實運用，幫助廠商大幅增進研發效率，提高新產品競爭優勢。例如加拿大的庫伯教授(R.G. Cooper)就根據他多年來在美加地區所從事的關於新產品研發的實證研究結果，開發出一套新產品成敗預測系統，來幫助加國廠商提高新產品開發的成功機率。他的系統經過多年的觀察，據稱在美加地區準確度高達80%，爲加國廠商省下極爲可觀的研發失敗成本（當然，這個系統的售價也極其昂貴）。本人藉旅居英國攻讀博士學位之便，依據國外文獻資料以及個人所從事的一些實證研究結論，也獨立開發出一類似系統，並願意免費提供國內參與本研究的廠商使用。

系統目的： 在眞正投入資金進行新產品研發之前，協助廠商更深入地檢討新產品研發專案所處的內外環境與可用資源，從而計算出本產品在各項成敗要因中的優勢劣勢地位，並估算本產品未來上市後的成功機率。
理論依據： 利用研究所得的數據資料建立高等統計模型，並依此模型推計可能結果。
軟體需求： MsDos 3.0 以上；與 Big 5 相容之中文系統（例如：倚天或中文 Windows）。
硬體需求： IBM 286以上相容型個人電腦；1Mb 硬碟空間；提供滑鼠支援。

因爲訪問內容與過去貴公司曾進行過的研發活動有關，所安排的受訪者煩請儘量選擇熟知研發專案狀況的人員，尤以研發單位負責人或專案負責人等爲佳，俾能在訪談時切中要點，充分掌握研發實況。

非常謝謝您費心安排這次訪談，正因爲有您熱心協助，本研究才得以順利進行下去，再一次謝謝您！請您在填妥回條後，利用傳眞機傳回。傳眞號碼是：

02－5812359
或　04－6874989

或是以郵件寄回：

周庭銳
台中縣大甲鎮文武里雁門路199-2號

回　　條

公司名稱：______________________________

服務單位：______________________________

級　　職：______________________________

受訪者 姓名：______________________________

方便接受訪問的日期 ______年______月______日
______午______時______分

訪問地點（地址）：______________________________

____

____

Appendix IV Quantitative Questionnaire

Managing Information for Effective Product Innovation

(Questionnaire for R&D executives or project team leaders)

PART ONE

A. Profiles of R&D Activities at Company Level:

1. Company Name: ____
2. When was the company established? __________________________________
3. How many new product development (NPD) projects have been actually implemented during the last 5 years? (including successful and failed cases) about _______ NPD projects.
4. On average, how many percent of new products were never commercialized? about _______ %
5. On average, how many percent of new products that were commercialized did achieve their original goals in terms of market success? about _______ %
6. On average, how many percent of total annual sales were from new product sales in the last 5 years? about _______ %
7. On average, what was the percentage of R&D expenditure account for the annual sales in the last 5 years? about _______ %

B. Profiles of Strategic Choices at Company Level:

1. If compared with the competitors, how do you rate the level of investment in R&D in your company?

   with little investment **1 2 3 4 5 6 7 8 9** with heavy investment

2. If compared with the competitors, how do you rate the management style of your company in terms of decision making?

   very conservative **1 2 3 4 5 6 7 8 9** very risk taking

3. If compared with the competitors, how do you rate the sensitivity or response speed of your company to the change of market situations or newly invented technologies?

   very slow and inactive **1 2 3 4 5 6 7 8 9** very quick and active

4. If compared with the competitors, how do you perceive the manufacturing style of your company?

   mass production benefits from economic scales **1 2 3 4 5 6 7 8 9** small scale with variant product models

5. If compared with the competitors, how do you perceive the general pricing policy of your company?

   large sales volume with low margins **1 2 3 4 5 6 7 8 9** high product quality with high margins

C. Profiles of the Interviewee:

1. Age: ______________________
2. Total working experience in years: ______________________
3. Experience with the present company in years: ______________________
4. Education: ______________________
5. Position in the company: ______________________

PART TWO

Profile of the New Product Development Project

Please answer the following questions considering the actual situation of this project.

A. Project (or product) name: ____________________
B. Project duration: from _____/_____(preliminary assessment) to _____/_____(launch)
C. Development cost (approximately): ____________________
D. Estimated product life cycle of this product: ____________________months
E. Strategic goals of this new product and the extent of the goals achieved:
(please circle a proper number for both the perceived importance and the final result for the following strategic goals)

	Strategic Goals	Perceived Importance of These Goals (Extremely Unimportant — Extremely Important)	Results in Achieving These Goals (Poor — Excellent)
1	Sales	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
2	Market Share	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
3	Profitability	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
4	Opportunity for entering a new business	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
5	Opportunity for entering a new market	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
6	Accumulating experiences, know-how, or technology for conducting other NPD projects in the future	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
7	To maintain or improve our leading image in the market	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

F. NPD project situations:
(please circle a proper number which best indicates the actual situation of this product when it was launched into the market)

	Project Situations	Completely Disagree — Completely Agree
1	We were expert in marketing or selling this kind of product.	1 2 3 4 5 6 7 8 9
2	We were expert in developing this kind of product in terms of technological know how.	1 2 3 4 5 6 7 8 9
3	We were very familiar with the production of this kind of product.	1 2 3 4 5 6 7 8 9
4	This was a highly innovative product -- the first of its kind on the market by any firm.	1 2 3 4 5 6 7 8 9

	Project Situations (continued)	Completely Disagree								Completely Agree
5	This was a highly innovative product -- there were very few firms able to use this kind of technology for developing this class of product.	1	2	3	4	5	6	7	8	9
6	This was a highly innovative product -- there were very few firms able to use this kind of production process for manufacturing this class of product.	1	2	3	4	5	6	7	8	9
7	This was a very sophisticated project in terms of the complexity of project management.	1	2	3	4	5	6	7	8	9
8	This was a very sophisticated project in terms of the technologies employed.	1	2	3	4	5	6	7	8	9
9	This was a very sophisticated project in terms of the manufacturing process employed.	1	2	3	4	5	6	7	8	9
10	All the core technologies for developing this product were sufficiently available in our company.	1	2	3	4	5	6	7	8	9
11	All the key components, systems, or materials for producing this product were sufficiently supplied by our reliable sources.	1	2	3	4	5	6	7	8	9
12	Compared with other projects in our company, this project was highly supported in terms of available budget.	1	2	3	4	5	6	7	8	9
13	Compared with other projects in our company, this project was especially supported by the CEO.	1	2	3	4	5	6	7	8	9
14	The original idea for this project was initiated by the market or our customer, rather than the technical breakthrough from our R&D.	1	2	3	4	5	6	7	8	9
15	In terms of technologies, we had a very clear idea from the very beginning of the project. We knew where the problems and solutions were.	1	2	3	4	5	6	7	8	9
16	In terms of product specification, we had a very clear idea from the very beginning of the project.	1	2	3	4	5	6	7	8	9
17	In terms of the definition of its target market and customer, we had a very clear idea from the very beginning of the project.	1	2	3	4	5	6	7	8	9
18	Compared with similar class of competitor products, this product provided better functions or benefits to the end users.	1	2	3	4	5	6	7	8	9
19	Compared with similar class of competitor products, this product provided better quality to the end users.	1	2	3	4	5	6	7	8	9
20	Compared with similar class of competitor products, this product was priced much higher.	1	2	3	4	5	6	7	8	9
21	There was great demand in the market for this kind of product.	1	2	3	4	5	6	7	8	9
22	The sales growth rate for this kind of product was predicted to be very high.	1	2	3	4	5	6	7	8	9
23	Price competition had been a major marketing tool for this kind of product.	1	2	3	4	5	6	7	8	9
24	There is a strong rival in the market for this kind of product.	1	2	3	4	5	6	7	8	9

PART THREE

Information Requirements/Transmission Patterns

According to the above selected project and the following 10 information items, how do you rate the necessity of these information items to the project? By what means and in which stages during its development process was the information actually acquired, transferred, and accumulated by your firm?

Information Item 1: Goal/Strategy Related Information
Goal/Strategy Related Information comprise corporate competitive strategy, expectation of new product performance, expectation of sales, standard of cost, quality, development schedule ... etc.

A. Compared with other NPD projects, how would you rate the necessity of this Information to this project? (please circle a proper number)

Extremely Unnecessary **1 2 3 4 5 6 7 8 9** Extremely Necessary

B. Overall, how would you rate the sufficiency and quality of this information acquired or generated for researching and developing this project? (please circle a proper number)

Extremely Unacceptable **1 2 3 4 5 6 7 8 9** Extremely Acceptable

C. According to the following NPD tasks or stages, what were the **major** stages for acquiring or generating this information for this project? (multiple choices, please tick your answers)

- ☐ didn't acquire, define, or generate this information at all
- ☐ regularly scanning this information for all projects
- ☐ information, know-how, experiences, or technologies learned from other previous projects
- ☐ Strategy Development Stage
- ☐ Idea Generation Stage
- ☐ Preliminary Assessment Stage
- ☐ Concept Development Stage
- ☐ Prototyping Stage
- ☐ Trial/Test Stage
- ☐ Commercialisation Stage

D. Refering to your answer in question C, please draw lines to describe the relationship amongst the following items concerning the actual situation of information acquisition activities during NPD. (Please draw lines to link the items from each category to one another; please also refer to the example attached with this questionnaire.)

Information Sources	Nature of Information	Informant	Transmission Channels	Information Users
(outbound) public sources fairs/shows/exhibits customers suppliers competitors distributors consultants research institute affiliated company *(inbound)* subsidiaries information centre top management R&D teams other departments others	direct interaction research/survey documentation observation	Top Management R&D department Marketing/Sales Purchasing Manufacturing Servicing Financial others	direct interaction electronic mail meeting seminar Fax/telephone documentation others	Top Management R&D department Marketing/Sales Purchasing Manufacturing Servicing Financial others

新產品研究發展策略、產品型態、資訊需求、與資訊運用模式之實證研究

（本問卷請由研發部門主管、研發專案負責人、或曾參與研發人員填答）

壹

A. 廠商基本資料

1. 公司名稱：______________________________
2. 公司創立年月：______________________________
3. 過去五年來新產品開發專案件數(含成功與失敗的專案)：約__________件
4. 平均而言，這些新產品開發專案中有多少百分比從未眞正上市過？約______%
5. 平均而言，在這些已上市的新產品中約有多少百分比眞正達成當初設定的策略目標，因而被認爲是成功的案例？約______%
6. 平均而言，過去五年來新產品銷售額佔年營業額百分比約______%
7. 平均而言，過去五年來每年研究發展經費佔年營業額百分比約______%

B. 廠商經營策略與現有資源評估

1. 和同業比較，本公司對新產品研發的重視和投入程度：

   落後甚多 1 2 3 4 5 6 7 8 9 極爲投入

2. 和同業比較，本公司的經營風格比較傾向於：

   穩健保守 1 2 3 4 5 6 7 8 9 創新冒險

3. 和同業比較，本公司對市場上新產品新技術的敏感度與應變能力相對如何：

   落後甚多 1 2 3 4 5 6 7 8 9 反應迅速

4. 和同業比較，本公司在製造技術上的特長偏向於：

   大量生產 1 2 3 4 5 6 7 8 9 少量多樣

5. 和同業比較，本公司的產品策略偏向於：

   薄利多銷 1 2 3 4 5 6 7 8 9 高品質高單價

C. 答卷者基本資料

1. 年齡 ______________________
2. 工作經驗 ______________________
3. 在目前公司中任職年數 ______________________
4. 學歷 ______________________
5. 職位 ______________________

貳. 新產品研發專案問卷

A. 專案或產品名稱: ______________________________

B. 專案期間: 由 ____/____(初步評估後認爲可行)至 ____/____(正式上市)

C. 研發成本(估計值)約合新台幣: ______________________________

D. 當時預計此一產品的生命週期約爲: ________________月

E. 新產品策略目標與達成績效評估:
(請逐項圈選該策略目標的重要程度並估計實際達成績效)

策略目標	目標重要程度 (非常不重要 → 非常重要)	實際達成績效 (極差 → 極好)
1 銷售額目標	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
2 市場佔有率目標	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
3 利潤目標	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
4 機會之窗(藉以踏入新的事業領域)	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
5 機會之窗(藉以踏入新的市場)	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
6 取得研發技術或經驗供未來使用	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9
7 保持或取得公司的市場領導地位	1 2 3 4 5 6 7 8 9	1 2 3 4 5 6 7 8 9

F. 新產品研發專案情境評估
(請就下列專案情境圈選最能代表您同意程度的數字)

專案情境	完全不同意 → 完全同意
1 我們對這類產品的行銷與銷售極有經驗	1 2 3 4 5 6 7 8 9
2 我們對這類產品的研發技術極爲熟悉	1 2 3 4 5 6 7 8 9
3 我們對這類產品的生產製造極爲擅長	1 2 3 4 5 6 7 8 9
4 就本產品的目標市場而言，這是一個創新度極高的新產品，是最早出現在這個市場上的產品之一	1 2 3 4 5 6 7 8 9
5 就本產品的技術層次而言，這是一個創新度極高的新產品，很少廠商具備這樣的技術來開發類似產品	1 2 3 4 5 6 7 8 9
6 就本產品的製造程序而言，這是一個創新度極高的新產品，很少廠商具備這樣的技術來生產 類似產品	1 2 3 4 5 6 7 8 9
7 就本專案的研發管理而言，這是一個相當複雜的專案	1 2 3 4 5 6 7 8 9
8 就本專案所採用 的研發技術而言，這是一個相當複雜的專案	1 2 3 4 5 6 7 8 9
9 就本專案所採用 的製造程序而言，這是一個相當複雜的專案	1 2 3 4 5 6 7 8 9
10 就核心技術而言，本產品所採用的關鍵技術幾乎完全掌握在自己手裏，不必自外引進	1 2 3 4 5 6 7 8 9

專案情境 (續)

		完全不同意								完全同意
11	就材料、零組件、系統的供應來源而言，我們有把握充份取得，不怕供應商予取予求	1	2	3	4	5	6	7	8	9
12	相對於公司其他專案，本專案在預算上獲得特別充分的支持	1	2	3	4	5	6	7	8	9
13	相對於公司其他專案，本專案特別獲得高階主管的重視與支持	1	2	3	4	5	6	7	8	9
14	本產品的原始創意基本上來自市場(或顧客)的啓發，而非肇始於公司內部的發想創造	1	2	3	4	5	6	7	8	9
15	對於本產品在研發過程中可能遭遇的各種技術問題我們自始即非常清楚，同時也知道去那裡尋求解答	1	2	3	4	5	6	7	8	9
16	我們對於本產品的規格自始即定義得非常清楚	1	2	3	4	5	6	7	8	9
17	我們對於本產品的目標市場與目標消費群自始即定義得非常清楚	1	2	3	4	5	6	7	8	9
18	和競爭產品相比較，本產品提供使用者一些特有的新功能、內涵、或是利益點	1	2	3	4	5	6	7	8	9
19	和競爭產品相比較，本產品提供使用者更好的品質或性能	1	2	3	4	5	6	7	8	9
20	和競爭產品相比較，本產品採高訂價策略	1	2	3	4	5	6	7	8	9
21	市場上對這類產品的需求很大	1	2	3	4	5	6	7	8	9
22	這個產品所屬的市場其銷售額年成長率極高	1	2	3	4	5	6	7	8	9
23	市場上銷售這類型產品的廠商其殺價競爭行爲極爲激烈	1	2	3	4	5	6	7	8	9
24	就這類型產品而言，市場上存在一個擁有高度市場佔有率的競爭對手	1	2	3	4	5	6	7	8	9

參.資訊需求與資訊傳送方式

請您繼續以前面這個新產品研發爲例，針對下列十種不同的研發資訊需求，分別估計該種資訊對本專案的必要程度，以及該資訊是在那個研發階段透過什麼方式取得和傳送的。

資訊項目：

(說明)

A. 和其他專案相比較，您覺得本專案是否特別需要這項資訊？(請擇一圈選)

非常不需要 1 2 3 4 5 6 7 8 9 非常需要

B. 整體而言，您覺得本專案所搜集到的這項資訊是否充足有用？(請擇一圈選)

完全不能接受 1 2 3 4 5 6 7 8 9 非常有用

C. 就下列研發階段而言，本專案在其中那些階段中曾實際搜集或創造此一資訊？

☐ 並未搜集或創造此一資訊
☐ 平時即隨時留意此一資訊，未特別爲本專案搜集
☐ 這項資訊係來自過去公司其他研發專案的資料
☐ 研發策略設定 ☐ 產品創意產生
☐ 專案初步評估 ☐ 產品概念發展
☐ 原型發展 ☐ 生產試作
☐ 量產上市

D. 依據您在第C題的答案，請您畫線連連看，描述下列資訊來源、資訊型態、資訊收集者、資訊傳送管道、與資訊使用者間的關係。

資訊來源	資訊型態	資訊收集者	資訊傳送管道	資訊使用者
(公司外部) 研究報告/報導/雜誌 商展 顧客 供應商 競爭廠商 銷售通路 顧問 研究機構/大學 合作廠商 *(公司內部)* 子公司 資訊中心 高階管理者 研發團隊 公司其他部門 其他來源	直接溝通/互動 研究調查 檔案文件 觀察	高階管理者 研發部門 行銷/銷售部門 採購部門 工廠 售後服務 財務部門 其他單位	直接溝通/互動 電子郵遞 會議 技術研討會 電話/傳真 檔案文件 其他方式	高階管理者 研發部門 行銷/銷售部門 採購部門 工廠 售後服務 財務部門 其他單位

資訊項目：

（說明）

A. 和其他專案相比較，您覺得本專案是否特別需要這項資訊？(請擇一圈選)

非常不需要　**1 2 3 4 5 6 7 8 9**　非常需要

B. 整體而言，您覺得本專案所搜集到的這項資訊是否充足有用？(請擇一圈選)

完全不能接受　**1 2 3 4 5 6 7 8 9**　非常有用

C. 就下列研發階段而言，本專案在其中那些階段中曾實際搜集或創造此一資訊？

- ☐ 並未搜集或創造此一資訊
- ☐ 平時即隨時留意此一資訊，未特別爲本專案搜集
- ☐ 這項資訊係來自過去公司其他研發專案的資料
- ☐ 研發策略設定　☐ 產品創意產生
- ☐ 專案初步評估　☐ 產品概念發展
- ☐ 原型發展　☐ 生產試作
- ☐ 量產上市

D. 依據您在第C題的答案，請您畫線連連看，描述下列資訊來源、資訊型態、資訊收集者、資訊傳送管道、與資訊使用者間的關係。

資訊來源	資訊型態	資訊收集者	資訊傳送管道	資訊使用者
(公司外部) 研究報告/報導/雜誌 商展 顧客 供應商 競爭廠商 銷售通路 顧問 研究機構/大學 合作廠商 *(公司內部)* 子公司 資訊中心 高階管理者 研發團隊 公司其他部門 其他來源	直接溝通/互動 研究調查 檔案文件 觀察	高階管理者 研發部門 行銷/銷售部門 採購部門 工廠 售後服務 財務部門 其他單位	直接溝通/互動 電子郵遞 會議 技術研討會 電話/傳眞 檔案文件 其他方式	高階管理者 研發部門 行銷/銷售部門 採購部門 工廠 售後服務 財務部門 其他單位

Appendix V Interview Structure

Open-end Questions for In-depth Interviews (Interview Structure)

PART ONE: The interview structure for R&D executives

1. A brief introduction to this study. A brief summary of the interview structure.
2. QUESTIONNAIRE: PART ONE was presented to the interviewee. The interviewee was then asked to answer the questions concerning corporate strategic choices, R&D activities at company level, and his (her) personal details.
3. Would you please tell me what are the CORE TECHNOLOGIES of your company?
(Core Technology is defined as the key capability or strength of the company which supports the development of all of their product lines and serves as the key source of product competitiveness.)
4. According to these core technologies, how many product lines have been devised and commercialised into the market? Would you please show me the structure/relationship of these product lines.
5. Would you please show me the organisational arrangements for R&D in your company. How many people have been assigned to the NPD activities? In general, how about their morale and turn over rate in recent years?
6. Would you please describe the general process of NPD in your company. Is there always a standard procedure for governing all NPD projects, or, on the contrary, NPD procedures were highly dependent upon different project type?
7. Will the departments other than R&D in your company (e.g., CEO, manufacturing, sales, marketing...etc.) participate in NPD activities? If any, in what situations and by what means are these departments able to contribute to the NPD projects?
8. Will the third parties (e.g., customers, suppliers, distributors, affiliated companies...etc.) participate in your NPD activities? If any, in what situations and by what means are these people able to contribute to your NPD projects?
9. According to the above product structure, would you please list as many as possible of the NPD projects conducted in the last 5 years. Several cases will thus be randomly selected from this list by using a random table.
10. The interviewee lists as many projects as he can on a paper with each project having an identical number. By the limitation of time and the wish of the interviewee, the number of cases which are going to be selected was given.
11. A case (or cases) for this study was selected according to a random table provide by the researcher. Each case was assigned a member from R&D department who knew well about the history of this project.

PART TWO: <u>The interview structure for project team leader or members</u>

1. A brief introduction to the study. A brief summary of the interview structure.

2. According to our selected project, would it be possible for you to show me the actual final commercialised product?

3. Over all, from both the technological and commercial point of view, how do you rate this product, as a successful or a failed one? Would you please explain the reason for its success or failure?

4. QUESTIONNAIRE: PART TWO and PART THREE were presented to the interviewee. The interviewee was then asked to answer the questions concerning this project. Personal details (i.e., age, working experiences, education, position in the company) of this interviewee were also recorded.

5. Would you please describe the history and the NPD process for this project?

6. Has any department other than R&D (e.g., CEO, manufacturing, sales, marketing...etc.) participated in this NPD? If any, in what situations and by what means were these departments able to contribute to this project?

7. Have third parties (e.g., customers, suppliers, distributors, affiliated companies...etc.) participated in this NPD? If any, in what situations and by what means were these people able to contribute to this project?

8. According to these information items listed in the questionnaire, would you please describe the information flows during this NPD?

9. During this NPD, how do you rate the communications:
   (1) between R&D and the third parties outside the company,
   (2) between R&D and other departments in the company, and
   (3) amongst R&D team members,

   in terms of richness and amount of information communicated?

10. Was there any special arrangement by your company which was believed to be extremely useful for facilitating this NPD?

11. What did your company do to preserve knowledge and experiences learned from this project? According to the turn over rate of R&D people in your company, what does your company do to keep the know-how from previous projects?

Appendix VI The Sample Firms

With special thanks to the following firms who participated in this study.

Acer Incorporated
Advanced Datum Information
Arche Technologies
Aten International
Behavior Design Corporation
Behavior Tech Computer
Cal-Comp Electronics
Chi-Yean Technology
China Motor Corporation
Chou Chin Industrial Corporation
Chun Yun Electronics
Compal Electronics
D-Link Corporation
Datatech Enterprises
DFI Computer and Electronic
Dual Enterprises
Dyna Technology
Echo Communication
Elitegroup Computer Systems
Enlight Corporation
ETEN Information System
Giant Manufacturing
Great Electronics
Ho Cheng Pottery
Kao Kang Wu Foods
Kunnan Enterprise
Logitech Far East
MAG Technology
Mao Sen Technology
Microelectronics Technology
Microtek International
Must Systems
President Enterprises
Rosa Foods Company
Sampo Technology
SDI Corporation
Tah Hsin Industrial Corporation
Taisan Enterprise
Taiwan Crystal Corporation
Taiwan Fu-Shin Industrial Corporation
Taiwan Singer
Ten Dao Corporation
Tsann Kuen Enterprise
Twinhead International
Ulead Systems
Ultima Electronics
Umax Data Systems
USI Far East
Vedan Enterprises
Yeu Tyan Machinery
Yulon Motor Corporation
Yung Shin Pharma Industrial Corporation
ZyXEL Communications

CHOU, Ting-Jui

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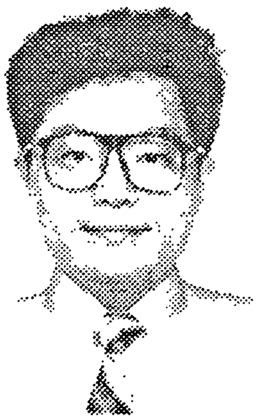
FAX: +44 (01203) 523719

周庭銳
台中縣大甲鎮文武里雁門路一九九之二號

199-2 Yen-Men Road, Tachia
Taichung, Taiwan, ROC
TEL: +886 (4) 6874989



Future Research Interests

- ***Organisational Learning in the Product Innovation Context***
- ***Strategic New Product Marketing***
- ***Machine-based Interactive Learning Systems for Product Innovation***

Current Interests and Capabilities

- ***Managing Information for Effective Product Innovation***
- ***Organisational Learning in the Product Innovation Context***
- ***Multivariate Analysis***
- ***Computer Programming under both DOS and Windows Platforms***

Education

10/92 - 11/95
Ph.D.

Warwick Business School, University of Warwick, Coventry, UK
Research Topic: Managing Information for Effective Product Innovation: A Contingency Approach

9/88 - 6/90
MBA

Graduate School of Business Administration, Chung-Yuan Christian University, Chung-Li, Taiwan
Major: Strategic New Product Marketing, Marketing Research, Management Information Systems

9/86 - 6/88
B.Sc.

Department of Industrial Management, National Taiwan Institute of Technology, Taipei, Taiwan
Major: Industrial Engineering, Management Information Systems

9/78 - 6/83
DIPLOMA

Department of International Trade, National Taipei College of Business, Taipei, Taiwan
Major: International Trade, Business Law

Working Experiences

4/90 - 10/92
YTM Group

Project Coordinator (1/92 - 10 92)
UK Office, YTM Group, Birmingham, England.
Participated in a team with 120 British fellow engineers for new vehicle design. ***Major Tasks:*** (1) UK-Taiwan liaison for project-related affairs, (2) project cost control, (3) system design for project-related information management.

Project Specialist (7/91 - 1/92)
Technology Research Centre, YTM Group, Yuan Lin, Taiwan.
Major Tasks: (1) system design for project-related information management, (2) organisational diagnosis for better product innovation management.

Assistant to President (4/90 - 7/91)
CEO Office, YTM Group, Taipei, Taiwan.
Major Tasks: (1) strategic new product marketing, (2) channel management.

Yeu Tyan Machinery (YTM) Mfg. Co., Ltd. is one of the largest corporations in Taiwan. It has diversified into a variety of industries such as vehicle, aerospace, machine tools, and supermarket.

9/90 - 8/91
CYCU

Lecturer (part-time)
Department of Business Administration
Chung-Yuan Christian University, Chung-Li, Taiwan
Course Taught: Management Information System

6/87 - 5/88
Jan-Jin Co.

System Consultant (part-time)
CEO Office, Jan-Jin Co., Ltd., Taipei, Taiwan.
Major Task: MRP system design and programming.

9/82 - 5/87
Marshal Co.

System Consultant (2/87 - 5/87, part-time)
CEO Office, Marshal Co., Ltd., Taipei, Taiwan.
Major Task: system design and programming for manufacturing quality control system.

Department Chief (9 85 - 3/86)
International Trade Department, Marshal Co., Ltd., Taipei, Taiwan.
Major Task: international trade

Clerk (9/82 - 8/83)
International Trade Department, Marshal Co., Ltd., Taipei, Taiwan.

Army Service

10/83 - 8/85
ROC Army

Chief of Welfare Department (5/84 - 8/85)
The Commissary of National Armed Force in Island Matsu, Fukien.
Manager of ten army-owned profit-making businesses.

Second Lieutenant (10/83 - 8/85)
National Armed Force, ROC
Political Chief of Company

Honors and Awards

1993 - 1995
Ph.D. Studies

Overseas Research Students Awards
Granted by the Committee of Vice-Chancellors and Principals, UK
The only student in the business school to win an award under this scheme during the period.

1988 - 1990
MBA Studies

Scholarship Student
Granted by the Tachia Agriculture Council, Tachia, Taiwan.
Granted for outstanding performance in academic work.

1983 - 1985
Army Service

Military Hero
Granted by the ROC National Armed Force.
I was the only soldier from my command post to be nominated in the honors list as the Military Hero of 1985. Granted for outstanding performance of logistic services for necessities.

1980 - 1982
Undergraduate

Scholarship Student
Granted by the Tachia Agriculture Council, Tachia, Taiwan.
Granted for outstanding academic credits.

1980
Undergraduate

Award of Sun Yat-Sen Theory Contest
Granted by the Ministry of Education, ROC, for the annual contest of Sun Yat-Sen Theory. I was the only student from my college who won this award in 1980.

Scholarly Publication

Effective Product Innovation Management
Chou, T.J. (1995), Managing Information for Effective Product Innovation: A Contingency Approach, University of Warwick, Coventry, UK. (Unpublished Ph.D. Thesis).

Chou, T.J. and V. Wong (1993), "How Corporate Information Requirements/Transmission Patterns Vary According to New Product Type: An Empirical Study," Working Paper Presented at the 22nd EMA Conference, ESADE, Barcelona, Spain, May, 1587-9.

Strategic New Product Marketing
Chou, T.J. (1990), ***Strategic New Product Marketing: The Taiwanese Cases***, Chung-Yuan Christian University, Chung-Li, Taiwan. (Unpublished MBA Dissertation)

College/Enterprise Cooperation
Jou, Y.H., P.B. Haung, and T.J. Chou (1989), ***A Study of the Cooperative Relationship Between Colleges and Enterprises in Taiwan***, The Science and Technology Advisory Group, Executive Yuan, ROC.

Professional Affiliations

CMA – Chinese Management Association (member)

Other Skills and Hobbies

System Analysis
Specialized in designing and implementing Database Systems and Executive Information Systems.

Operation Systems
Dos, MSWindows, Unix (Linux).

Software Development
Experienced programmer of Basic, Fortran, Cobol, dBase, Pascal, and Prolog languages under both DOS and Windows platforms.

Capability of using Object-Oriented Programming techniques for commercial software development.

Capability of using Artificial Intelligence theories for developing Expert Systems or interactive knowledge bases.

Capability of writing programmes that use the MCI and Microsoft Video services, i.e., sound effects and picture animations for multimedia presentation.

Familiar with the API internal function calls for Microsoft Windows.

Computer Networking
Former network supervisor of Novell Netware systems.

Capability of developing WWW pages for InterNet.

Familiar with common services provided by the InterNet, such as E-Mail, FTP, Gopher, . . . etc.

Marketing Research
Highly proficient in conducting marketing survey.

Familiar with both the Univariate and the Multivariate Techniques.

Familiar with statistic softwares such as SPSS or StatGraphics for data analysis.

Capability of writing customized programmes for further data analysis.

Other Skills
Desktop Publishing

Professional Typist (80 words per minute)

Personal Data

Birth Date:	16, October, 1961
Birth Place:	Taiwan
Nationality:	Taiwan, ROC
Native Language:	Chinese (Mandarin)
Sex:	Male
Height:	5'5"
Weight:	148 lbs.
Health:	Excellent
Marriage:	Married with one boy.

REFERENCES FURNISHED UPON REQUEST